The making(s) of more-than-human design
Introduction to the special issue on more-than-human design and HCI

Giaccardi, Elisa; Redström, Johan; Nicenboim, Iohanna

Important note
To cite this publication, please use the final published version (if applicable).
Please check the document version above.

Taylor & Francis
Taylor & Francis Group

Check for updates

The making(s) of more-than-human design: introduction to the special issue on more-than-human design and HCI

Elisa Giaccardi [a], Johan Redström[b], and Iohanna Nicenboim [c]

aDepartment of Design, Politecnico di Milano, Milan, Italy; bUmeå Institute of Design, Umeå University, Umeå, Sweden; cDepartment of Human-Centered Design, Delft University of Technology, Delft, The Netherlands

ABSTRACT

Human activities have drastically altered the planet, with design playing a significant role. While design may intend to do good, its consequences are not always positive: from climate change to resource depletion to unforeseen social dynamics. These transformations also include ourselves, as our relationships with new technologies blur and complicate previous human and machine agency distinctions. Increasingly, design has become a matter of defining what it means to be human. This special issue explores the proposition that conventional human-centered design approaches may not adequately address the complex challenges we face, and that there is instead a need to ground design in more-than-human perspectives. This introduction outlines the evolving landscape of more-than-human design in the context of HCI. Articulating a series of emerging research trajectories, we aim to illuminate the transformative potential of more-than-human orientations to design, including how they both extend and depart from familiar lines of inquiry in HCI – for example, how designers are redefining data, interfaces, and responsibility, and reshaping posthuman knowledge through design. Ultimately, this special issue aims to explore new pathways for designing in the era of the more-than-human, challenging the perceived divide between practice and theory to imagine alternative futures for HCI.

1. Introduction

As humans, we are transforming the planet. Indeed, it is to a considerable degree the explicit aim and ambition of design to do so. While there is often a beneficial intent to design, the transformative consequences of design are not always positive: from climate change to resource depletion to the unforeseen implications of social media technologies. Through design, we are also transforming ourselves. Whether it is about reducing the burden of remembering birthdays, automatically trading stocks or using algorithmic decision systems to manage insurance claims or job applications, the significant potential and possibly devastating consequences of extending beyond individual human actions are evident – we now share agency with machines that are increasingly capable yet also ontologically opaque. Throughout these pressing challenges, there is growing concern that the human-centeredness that characterizes design's current foundations is reaching its limit.

Much of contemporary design practice has developed in relation to perspectives and contexts that prioritize human needs and desires. From the explicit focus on the "user" in human-centered design to the notion of the Anthropocene, these perspectives build on the human exceptionalism of the Western humanist tradition, including the aesthetics and ethics associated with it. However, this has, in fact, elevated certain human needs and desires at the expense of all other forms of life and has also privileged the needs and desires of some humans above others.

Historically, the positive effects of user-centeredness when it comes to caring for human needs and desires in mass production and technology development cannot be overstated. However, it is also increasingly evident that this perspective falls short when addressing the intricate interconnections between human needs/desires and broader ecosystems. Particularly with the emergence of contemporary technology blurring traditional boundaries between users/designers, producers/consumers, and human/nonhuman performers (Giaccardi & Redström, 2020), human-centered approaches struggle to adequately address the multifaceted challenges we confront today – spanning ecological, societal, and technological realms – in ways that are both inclusive and sustainable. To effectively tackle these issues, it is imperative to move beyond narrowly modernist views of humanity and recognize reality as encompassing more than just the human experience. In essence, embracing the concept of the more-than-human is crucial.

As this new orientation or design approach gains traction in HCI, one might find oneself asking what new perspectives and possibilities it actually brings, and to what extent it is a matter of merely stating already familiar matters in new ways. However, whether posthumanist perspectives on design represent a paradigmatic change or not, is a question better saved for later. First, we must address another matter – as the evolving design research under this banner allows us to learn more about the transformative journey involved in making use of new concepts.

Concepts are not given or handed over, they are continuously made and constantly remade. There is a crucial difference between thinking of theory as something we "just" apply in design, and thinking about theory as something we *make use* of in, and through, design. As notions such as "posthuman" and "more-than-human" *make* their way into design and HCI, something happens to them. When the constellations of problems, practices and concepts that they originated from, are replaced by other problems, other practices, and in relation to other concepts, they change.

Some of the papers in this issue highlight this performative aspect of theory. For example, Fuchsberger and Frauenberger (this volume) reformulate responsibility as something that should be *enacted* within hybrid assemblages of human/nonhuman relations. Van Beek et al. (this volume) reconceptualize everyday crises of co-performance between people and technology as a site for *improvising* posthuman interfaces. Lindley et al. (this volume) propose to generatively oscillate between different theoretical perspectives as a strategy for *doing* more-than-human design. Nicenboim et al. (this volume) review how more-than-human designers (re)shape posthumanist knowledge *through* deliberate acts of decentering. Beyond materializing theory, these articles open up new epistemological paths for designers allowing them to actively produce designerly posthumanist knowledge.

New perspectives inevitably trigger change. It is precisely this juncture that this special issue aims to capture, as we remain open about the impacts these concepts and practices will have on HCI. Whether they introduce genuine novelty to this field, we are keen on observing this reciprocal process of transformation unfold. In doing so, we hope to learn something about the design potentials of these ways of knowing and doing, offering fresh perspectives on both longstanding and emerging questions and challenges. Moreover, we also hope to learn something about how HCI might evolve in light of pressing contemporary challenges, drawing on ideas cultivated outside its traditional boundaries.

In what follows, we explore the question of how to consolidate a wide array of posthumanist approaches to design and HCI under the overarching idea of the "more-than-human." Initially, we map out the terrain of societal concerns and philosophical perspectives, within which different research paths intersect to form fruitful configurations. The intention behind outlining these research trajectories is not to rigidly define or categorize the foundational elements of more-than-human perspectives in design and HCI, whether within established HCI traditions or the broader posthumanist scholarship that informs them. Instead, our aim is to discern the legacies that are *both upheld and transformed* by the concepts, understandings, and methodologies of more-than-human design. This approach does not entail exhaustive mapping, labeling, or the creation of a lexicon; rather, it seeks to illuminate the evolving nature of designing within the more-than-human paradigm.

By attending to these potential paths, we then seek to investigate how the authors in this special issue both align with and depart from these trajectories. As authors strive to conceptualize and develop new avenues for meaning and action within the co-performance of humans and nonhumans – a core aspect of more-than-human design – their movements within these trajectories help us articulate, speculate, and explore what research programs are currently unfolding in this area.

2. At the intersection of societal concerns and philosophical orientations

Societal concerns and philosophical orientations are intricately intertwined in the ethos of more-than-human design (Tironi et al., 2023). At its core, more-than-human design recognizes that human society exists within a complex ecosystem of interactions involving not just humans, but also various non-human performers such as technology, animals, and the environment. Pressing issues like climate change, resource depletion, and the ethical dilemmas posed by advancing technologies underscore the conceptual and methodological inadequacy of human-centric perspectives in addressing contemporary challenges. Furthermore, these challenges prompt an alignment with growing calls for inclusivity, sustainability, and decoloniality, emphasizing the necessity for developing and committing to design approaches and practices that account for the broader ecosystem in which humans operate. In other words, societal concerns inform the adoption of theoretical perspectives that emphasize interdependence, inclusivity, and agency. Conversely, theoretical perspectives provide the conceptual tools for designers to address societal concerns and approach the act of designing in ways that reflect a broader understanding of the relationships between humans and their environment.

Within the domain of posthumanist HCI, a diverse range of ontologies and epistemologies are drawn upon. Frameworks such as actor-network theory (ANT), object-oriented ontology (OOO), postphenomenology, new materialism, agential realism, and feminist posthumanities are among the most prominent (Forlano, 2017; Frauenberger, 2019; Wakkary, 2021). These theories provide valuable insights into understanding and addressing the current challenges faced by design. They interrogate anthropocentric assumptions by stressing the interconnectedness between humans and non-humans, encouraging designers to contemplate the agency and perspectives of non-human actors. Furthermore, they highlight the co-performance of human and non-human actors in sociotechnical systems, underscoring the importance of acknowledging the interdependence and intrinsic entanglement of humans, technology, and the environment within design processes.

A distinguishing feature of the adoption of posthuman theories in design and HCI is the shift away from a predominantly human-centered design (HCD) approach and the turning toward more-than-human orientations. Rosi Braidotti (2019), a leading contemporary feminist theorist renowned for her contributions to posthumanism, argues that the posthuman turn signifies the convergence of two critiques: one that challenges anthropocentrism and another that questions the normative, Eurocentric, and humanist notion of the human as male, white, and able-bodied. In line with the perspectives of other influential feminist theorists (Barad, 2007; Grosz & Stirner, 2016; Haraway, 1991; Hayles, 1999), she asserts that posthumanism fundamentally challenges all dualistic viewpoints, including those between human/animal, human/machine, life/death, organic/synthetic, natural/artificial, and similar dichotomies. What posthuman perspectives share is not a rejection of the human, but rather a repositioning of the human within broader ecologies and temporalities.

From this position, scholars and designers in HCI have developed and articulated an already extensive array of different concepts, methods, and practices (Coskun et al., 2022; Yoo et al., 2023). Examples of concepts include constellations (Coulton & Lindley, 2019), entanglements (Frauenberger, 2019; Hodder, 2012), fluid assemblages (Redström & Wiltse, 2018), and co-performance (Kuijer & Giaccardi, 2018). Methods employed encompass ethnographic research involving nonhumans (Giaccardi et al., 2016; Murray-Rust et al., 2019), autoethnographic practices of noticing differently (Biggs et al., 2021; S. Liu et al., 2019; Oogjes & Wakkary, 2022), and material speculations (Biggs & Desjardins, 2020; Desjardins et al., 2021; Devendorf & Ryokai, 2015; Lindley et al., 2018; Nicenboim et al., 2020; Oogjes & Wakkary, 2022; Wakkary et al., 2017). These methods

have been used/applied to engage with diverse agencies, including animals (French et al., 2020; Mancini, 2017), plants and forests (Biggs & Desjardins, 2020; Tomico et al., 2023; Westerlaken et al., 2022), bacteria (J. Liu et al., 2018; Ofer et al., 2021; Zhou et al., 2023), food (Dolejšová et al., 2020; Wilde et al., 2021), materials (Dew & Rosner, 2018; Oogjes & Wakkary, 2022), things (Coulton & Lindley, 2019; Giaccardi, 2020; Reddy et al., 2020; Wakkary et al., 2017), and intelligent agents (Desjardins et al., 2021; Forlano, 2023; Nicenboim et al., 2023; Treusch et al., 2020).

3. A field in the making

With such a vast array of concepts, methods, and practices being developed, it can be useful to call some of the resulting research trajectories to the fore to get a sense of how this emerging research field is being *made*. The formation of a field does not happen in an instant. On the contrary, the research trajectories evident in this special issue all have roots in various origins, with some tracing back to the early stages of design and industrialization, while others stem from more recent times. Whether continuity or discontinuity underlies the propositions made in the papers included in this special issue, there are themes – or perhaps better, different constellations of research trajectories – that emerge and are useful to discuss, as we come to learn more about the potentials and challenges of posthumanist orientations in HCI and design.

To invite and inspire reading not only each contribution on its own, but to read across them, to juxtapose and to also get a sense of the tensions and spaces between them, in what follows we will introduce a series of constellations as potential starting points for further exploration. The point is not to be comprehensive, or to somehow define what directions are now evident in this emerging field, but to offer illustrations of how the works included in this special issue connect to each other as well as to the traditions and discourses in design and HCI they relate to. This kind of reading is fundamentally pedagogical. In two ways. First, it helps develop approaches and narratives that are consistent with the theories and the turns being engaged (not just in the posthumanities but also in design theory). As stated by (Redström, 2020): "designing will more actively engage in making the concepts and conceptual spaces needed to open new possibilities and address complexity. But neither research nor theory will be used to bring order and stability to design. On the contrary, we will use them to make things less certain." (p. 99) Second, it facilitates connections in a non-territorializing manner, steering clear of the pitfalls of decontextualizing and diluting the profound essence of both old and new ideas (Tlostanova, 2021), and diminishing the likelihood that a "critical term today can become a catchy phrase tomorrow, and a cliché (or brand) the next" (Foster, 2002, p. 24).

Each constellation offers a mix of epistemological, theoretical, and methodological questions. We have curated them according to the following five design issues:

(1) How are we entangled?
(2) Whom or what do we include and design with?
(3) How do we give them voice and represent them?
(4) What matter comes to matter?
(5) What is the role of design in more-than-human worlds?

In addressing these concerns, the sections that follow intersect, assemble, and diffract notions and traditions in HCI and design. The first constellation intersects concepts such as system, environment, and ecology (examining our entanglements); the second constellation, ideas surrounding participation as a design resource, fundamental right, and ontological condition (considering whom or what we include and design with); the third constellation examines values stemming from posthumanist, feminist, and decolonial perspectives (exploring how humans and nonhumans are voiced and represented through design); the fourth constellation considers materiality, bodily experience, and relational becomings (inquiring into how "matter comes to matter," borrowing the expression from Barad, 2003); and the last constellation is about perspectives on post-

anthropocentrism, more-than-human design practice, and planetary challenges (addressing the role of design in more-than-human worlds).

4. Design issue 1: cutting across messy realities

While notions of "use" and "usefulness" might appear completely obvious starting points for design, they nevertheless introduce a fundamental tension between the object and its context: useful for whom and where, and for what purpose? When considering what design taking a more-than- human world into consideration might be like, such tensions immediately become more pressing. Add to this design's role in industrial production, and a range of issues regarding production, distribution and consumption, and the implications of design beyond the intended use situation become critical to consider. Indeed, there are reasons why notions of systems, environments and ecologies have been central drivers behind many key methodological developments in design. Of special relevance to the theme of this issue, it is worth recalling the strong connections between the emergence of systematic design methods in the late 1950's and 1960's, and the development of the technologies now addressed in more-than-human design, such as artificial intelligence.

Importantly, with systems and environments we do not only come across matters such as networks, feedback, relations and positions, interiors and exteriors, but also very basic questions about knowledge and what this means for how design relates to uncertainty and control. With respect to such rich and central trajectories in design research, the notions of entanglement and ecologies activated in more-than-human design seek new perspectives on partly familiar problems. In other words, what they bring is not necessarily a capacity to articulate and approach issues that we previously could not address at all, but rather to allow us to do so in a way that differs from current practices. As Özçetin and Wiltse (this volume) discuss in their paper in this special issue regarding the challenge of addressing the complex systemic issues entailed by terms of service: "This requires, somewhat paradoxically, shifting focus away from the immediate experience and goals of end users to instead focus on the complex networked ecosystems behind the things they interact with – aiming to make these legible in ways that actually complicate and challenge moments of use." (add page).

In this new condition, the one-to-one relationship between person and object that is still foundational to much design has been irreversibly replaced with such a complex networks of relations that we struggle not only with what we (need to) know about some part of the world to design well, but also almost existential questions of *who* are *we* to design "the world." Clearly, "we" is no longer some more or less extended or extrapolated version of "me," but just how far toward an open and therefore also increasingly indeterminate orientation toward both human and more-than-human entities have we actually come? Indeed, several fundamental concepts such as intentionality and responsibility in design, which we typically contemplate in more individualistic terms, now require reevaluation. Exploring how shared responsibilities also open up for questioning the relations between humans and machines, Fuchsberger and Frauenberger (this volume) state in their paper in this special issue that: "Considering responsibilities as being shared instead of distributed allows us to depart from the idea that humans and machines possess different proportions of responsibility that together bear full responsibility (or fail to do so). Rather, responsibilities being shared means that no actor, human or not, can withdraw from doing responsibilities" (add page). The "implications for design" of such an understanding of what is a matter of genuinely shared concern, are considerable.

5. Design issue 2: assembling participation beyond people

An ongoing trend in both HCI and design has been the gradual expansion of the scope of interactions addressed, along with the methods employed. For instance, fields like computer-supported collaborative work (CSCW) and design methodologies like participatory design have evolved to tackle not only increasingly complex interactions but also the interplay between individuals, technology, and their usage contexts. This broadening design landscape encompasses various dimensions, but concerning participation, two primary motivations emerge: considerations of resources and rights – or, perhaps better, the poetics of design on one hand, and its politics on the other.

As soon as a design objective becomes complex enough that a single person cannot deal with it alone, there comes a need to tap into the resources of the others' expertise and experiences. Whether it is a matter of forming design teams, interdisciplinary constellations or involving people representing intended users, these are fundamentally matters of making knowledge, expertise, as well as experiences and worldviews present and active in the design process, often with a focus on how the end outcome or product will benefit (or indeed, be a better fit). In this sense, work conducted in the 1980s and 1990s in CSCW provided important design considerations for collaborative environments beyond individual users, articulating the challenges and implications of designing computer systems to support collaborative work in various contexts (e.g., Bannon & Schmidt, 1989; Grudin, 1994). However, there are also other reasons why participation might be central to designing: design has implications, and in this process of transformation the ones affected – the ones being designed *for* – should have a say. Especially in Scandinavia, the origins of participatory design are directly connected to processes of democracy in the workplace, and the right to have a say in matters that affect you. Between the 1970s and 1990s, the numerous design and HCI communities that contributed and eventually converged around the Participatory Design Conference played a significant role in promoting democratic principles in technology development (e.g. Bødker et al., 2022; Shuler & Namioka, 1993).

The two trajectories are not mutually exclusive, but they do not always come together, either. In the context of more-than-human design, we can see traces of both. While the incorporation of other species into the design process may stem from ethical considerations and a desire to embrace diverse worldviews, the notion of technology engaging in participation rather than merely serving as a tool may seem less intuitive. Yet, this shift underscores the evolving orientations pursued by more-than-human design. While the agency of things and technologies have been studied for quite some time, there are significant distinctions with respect to how "participation" is defined and designed. This dichotomy highlights the difference between mere utilization and active collaboration or co-performance within the design process (Kuijer & Giaccardi, 2018). It is also, it should be noted, a way to become more aware and explicit about the fact that some of the technologies now addressed have agency and potential to act that extends far beyond anything we have ever lived with before, to the point where it might even be misleading to think of our relations in terms of "use."

Regarding such basic questions as to what it means to take part in something, one challenge is to align the vastly different scales of time and space involved. In their paper in this special issue on rethinking design workshops, Wilde and Lenskjold (this volume) remark: "One challenge to overcome in this endeavor is the temporal constraints of workshop activities that follow different timelines than the process of consuming, digesting, and excreting bodily waste, and thus the time involved in waiting to receive a bodily reaction" (add page). Interestingly, while decentering the human might seem to require that we also challenge the central role of human experience, it appears as if experience is still central, but that we might need to approach it differently. An illustration can be found in the paper by Lee, Speed, and Pschetz (this volume) in this special issue on how to renew notions of data for ecological thinking, exploring how to expand perceptions of data "from conventional taken records and information to improve human life, to contextual features (i.e., colors, shapes, movements, rhythms, and cycles) given by entities, and which ultimately draw attention to the autonomy, agency, and livingness of nonhuman beings and the environment" (add page).

6. Design issue 3: diffracting representation and decentering

The concept of coexisting within larger ecosystems alongside other species and assuming responsibility for matters beyond human needs and desires is often grounded in values of inclusivity and democratic involvement in design processes. However, as we have indicated, fostering participation in more-than-human design may be less about granting moral rights or positions to other species or artificial intelligence and more about acknowledging how the world actively shapes and reshapes itself. In this sense, participation in more-than-human worlds is not a gift bestowed by designers upon non-designers; rather, it is the "fundamentally participative relation" (Giaccardi, 2020, p. 102) that comes to expression in the encounter of capabilities and doings uniquely human and uniquely nonhuman, toward which the locus of contemporary design is shifting.

The articles in this constellation (Fritsch et al., this volume; Søndergaard, this volume; Nicenboim et al., this volume) explore how nonhuman perspectives and trajectories come to be accessed and represented in the crafting of these encounters. For this, the authors draw from feminist posthumanities to emphasize inclusivity, diversity, and the importance of considering various perspectives and worldviews, including those that do not originate from humans. The authors stress how the way in which we perceive, engage with, and represent such perspectives is always relational and situated; in other words, it depends upon one's personal and social identities, cultural experiences, and many other intersecting factors, including the existing power structures in which human-nonhuman relations come to expression. This call to researchers and designers to engage in reflexivity and critically assess their own perspectives and biases, while considering other-than-human perspectives, is deeply embedded in the tradition and activism of Feminist HCI outlined by Shaowen Bardzell about a decade ago (Bardzell, 2010). Reflecting on the boundaries and attitudes toward the worlds we inhabit, or may inhabit, Søndergaard (this volume) asks in this special issue: "So what do you, as an interaction designer, HCI researcher and feminist, do in this literal and disciplinary 'race for space'? You could join, keep a distance, or critique from within. Rather than following transhumanist discourse and techno-utopian imaginaries of domination and control, of colonizing space through military action, I joined with feminist science fiction authors, such as Ursula K. Le Guin, in troubling and reimagining space, science and technology narratives through values of care and mess, for purposes of not going to space, but telling us something about care on Earth" (add page).

The recognition and representation of diverse perspectives, values, and knowledge systems go hand in hand with taking seriously the historical imbalances and power structures that come into play in designing. Challenging anthropocentric worldviews and structures through decentering (Nicenboim et al., this volume), breathing-with (Fritsch et al., this volume), and fabulating (Søndergaard, this volume) aligns with and strengthens aspects of the decolonial design agenda in HCI (cf. Rosner, 2020). To celebrate alternative ways of knowing and interacting with technology or other species on the basis of the coexistence of multiple worldviews and the acknowledgment of pluriversal values, the authors in this constellation propose more-than-human concepts, methods, and practices that share with decolonial design attention to epistemic inclusivity (Nicenboim et al., this volume), power redistribution (Fritsch et al., this volume), and the importance of narrative and storytelling as a way to challenge monolithic and homogenized representations (Søndergaard, this volume). These approaches contribute to dismantling the dichotomies of Eurocentric and Western-centric design legacies, including center/periphery distinctions. In their paper, Nicenboim et al. (this volume) dive deep into what layers of norms and assumptions are being "peeled back" when decentering and accounting for new actors: "While the notion of decentering is commonly utilized in posthumanist HCI, designers and researchers have employed the concept in related yet distinct ways. There is often ambiguity regarding what is precisely intended when employing that term, i.e., what/who is being decentered, what/who is accounted for (centered)" (add page).

At the same time, the more-than-human concepts, methods and practices discussed by the authors in this constellation transcend and expand feminist and decolonial agendas by recognizing that the species and things we interact with are not merely resources or passive objects, but entities

with a form of agency that demands ethical consideration. Ethics and rights in the context of AI is a massive topic, with numerous implications for how HCI will have to adapt and evolve to acknowledge and facilitate a more reciprocal and responsible engagement between humans and the nonhuman entities. Through practices of decentering, breathing-with, and fabulation, propositions are made that mobilize these diverse agendas, reflecting on how they intersect and interact.

7. Design issue 4: mattering matter and relational becomings

The posthuman turn prompts a rethinking of how materials are conceptualized and engaged within HCI and design. However, this rethinking should be viewed in the context of a broader shift toward materiality and performativity within HCI (Giaccardi & Karana, 2015), and against the backdrop of discussions in closely related fields such as science and technology studies (STS) and philosophy, especially in the research around feminist technoscience and new materialism. Sociomateriality, for example, has been critical to understanding materiality within technologically embodied interactions in HCI (Dourish, 2001) and its practical implications (Orlikowski, 2007). Sociomateriality challenges the traditional dichotomy between technology and society, suggesting that human actions and material artifacts are interwoven and cannot be understood in isolation. While sociomateriality acknowledges that human agency is distributed across a network of human and nonhuman actors, new materialism extends the relational and performative aspects of materials by exploring agency as an emergent force arising within intra-actions (Barad, 2007). Intra-action suggests that subjects, objects, and materials do not exist as separate entities before they interact; instead, they co-create each other through their relationships. Thus, rethinking "how matter comes to matter," new materialism recognizes the material world not as a silent backdrop or inert stage upon which human activity unfolds, but as a vibrant field where active processes of significance are continually unfolding within ecosystems (Bennett, 2010).

The articles in this constellation point to materials as alive and vibrant, worthy of a renewed consideration. Lee, Speed, and Pschetz (this volume) use tomatoes as a provocation to move from the "datafication" of species to a form of "pheno-fication" of data, inviting designers to "pay attention to tomatoes' tangible bodies and movements, their engagement and configuration in a polyphonic rhythm of the lifeworld, as well as to unknown and known local, geographical, and evolutionary stories of them" (add page). Fritsch et al. (this volume) propose a soma design tactic in which designers can "move from the intimate experience of our own bodies into an extended bodily awareness that included the more-than-human as material, living and social bodies" (add page). Similarly, Wilde and Lenskjold (this volume) work with substantial material interchanges to explore and problematize human-microbe relations. This attention to the new materialist aspects of materials and "mattering" signifies a shift in HCI traditions from human-centered foundations toward a notion of "becoming," which emphasizes ontological continuity and acknowledges the material interconnectedness among the various bodies involved in design processes.

8. Design issue 5: reworlding design

Human-centered design (HCD) is an approach that prioritizes the needs and preferences of humans throughout the design process. As discussed in the opening of this editorial, HCD has been highly effective in creating products and systems that meet individual user or group requirements, but it does have limitations when viewed from a broader planetary or ecological perspective. It is inherently focused on short-term needs and consumption habits, and it tends not to fully consider the long-term environmental or social consequences of the products and systems designers create. Even when attempting to be ethically aligned and principled, it may not adequately consider the needs of future generations or nonhuman entities, because of a lack of the appropriate conceptual and methodological orientation. The increasing awareness within posthumanist HCI regarding the unintended ramifications of prevailing design paradigms and the systemic influence of design on

a global scale informs this final constellation. This underscores a key aspect driving the shift away from human-centric perspectives and urging designers to contemplate the wider repercussions of their practice on ecosystems, climate, and the planet as a whole.

In her book "Staying with Trouble" (Haraway, 2016), Donna Haraway introduces the concept of "reworlding," which involves actively reshaping and reconceptualizing our perceptions of the world, often by deconstructing established narratives surrounding gender and identity. The authors in this last constellation "reworld" conventional understandings of how we relate to and engage with technology (van Beek et al., this volume) and how we make sense of technology (Wilkie & Michael, this volume). Their endeavor aims to cultivate tools for designing from a post-anthropocentric viewpoint, which can offer solutions beyond the limitations of human-centered orientations when confronting global issues like the climate crisis. By promoting a more fluid and dynamic perspective on how humans interact with technology and society, their work dismantles established roles and identities within the design process. This includes reconsidering who or what has the agency to redefine relationships and instigate change.

According to van Beek et al. (this volume), the process of reworlding design during times of crisis demands a reconsideration of the role of design within professional practice. This entails designing technologies that foster resilience and sustainability within socio-technical systems, recognizing the interconnected nature of human and nonhuman actors and embracing more imaginative (Wilkie & Michael, this volume) and recursive (van Beek et al., this volume) approaches to design. By reconceptualizing interfaces as a more-than-human site of productive friction, van Beek et al. (this volume) argue: "Designers might turn their attention to design for conflict and deliberation and consider how it might turn into a productive dialogue." This places human designers in the position of facilitating co-performances, requiring them to be attentive to existing power imbalances and conscious of political agendas and narratives in technology development. Similarly, in contrasting the terms "design brief" and "system requirements," Wilkie and Michael (this volume) add: "rather than ready-made negative obstacles to be overcome by 'herculean' (Deleuze, 2001, p. 158) design efforts, design problems are fabricated and posed in the design process and, in part, activated by the problematic of the brief. If we are to take the more-than-human seriously, and not simply historicize it as a feature of contemporary technological 'progress' (e.g., that interactive and computational technologies bring about other-than-human agency), then, as we outline above, all manner of living and non-living entities and phenomena count as the more-than-human and partake in the design event, including design briefs, problems, and ideas with their own peculiar manners of existence and becoming" (add page).

9. Contributions to this special issue

9.1. "Doing responsibilities in entangled worlds" by Verena Fuchsberger & Christopher Frauenberger

In their article "Doing responsibilities in entangled worlds," Verena Fuchsberger and Christopher Frauenberger (this volume) explore the concept of responsibility from a posthuman standpoint in the context of HCI and interaction design. They begin by examining the philosophical origins of responsibility and how it is currently perceived in HCI. Then, they argue that existing views on responsibility are inadequate for capturing the complex realities arising from the intertwining of humans and emerging technologies. Utilizing posthumanist perspectives, they advocate for rethinking where responsibilities reside or are enacted within hybrid assemblages of relations. By considering responsibility as an action that is "done" within these assemblages, Fuchsberger and Frauenberger present it as a fluid concept, grounded in relationships rather than fixed entities, and dispersed over time. They propose that responsibility begins in various innovation environments, extends into design practices, and continues into the usage and appropriation of technology. The article discusses how this notion of "doing responsibilities" can be useful for examining changes

within an assemblage. This conceptual contribution importantly reorients the prevalent notions of responsibility in HCI to focus on "doing responsibilities," emphasizing its enacted and relational nature.

9.2. "Terms of entanglement: a posthuman reading of the terms of service" by Seda Özçetin & Heather Wiltse

In their article "Terms of entanglement: A posthuman reading of the Terms of Service," Seda Özçetin and Heather Wiltse (this volume) address the complex relations in contemporary connected devices focusing on the governance of these relations through Terms of Service (ToS). They argue that the current practice of obtaining consent via ToS is inadequate for mediating these multifaceted relationships, which often involve ongoing updates and data production. Drawing from posthuman perspectives, the authors explore three design strategies to rethink design practices toward democratic data governance in relation to ToS: examining entanglements, decentering perspectives, and co-performance. Through these strategies, they develop a design practice that meaningfully exposes and makes actionable the complex networked relationships in connected devices, which they term "revealing design" practices.

9.3. "Pheno-data: using tomatoes to rethink data and data practice for ecological worlds" by Youngsil Lee, Larissa Pschetz, and Chris Speed

In their article "Pheno-data: Using tomatoes to rethink data and data practice for ecological worlds," Youngsil Lee, Larissa Pschetz, and Chris Speed (this volume) delve into the prevailing notions of data, noting how they are increasingly centered around digital representations. This focus tends to prioritize the efficiency and productivity of global economic systems, often at the expense of tangible and local information that is vital for more-than-human worlds. To counter this trend, the authors introduce the concept of "pheno-data," designed to capture the living essence of the lifeworld through the dynamic characteristics and behaviors of organisms. Alongside this, they present "pheno-fication" as a method to access pheno-data. The article uses the example of tomatoes to demonstrate this process. To bring these concepts into the realm of practical application, a fabulation workshop is conducted. This workshop aims to integrate these ideas into design practice, providing a hands-on opportunity to explore their potential. Through this process, the authors aim to shift perspectives from an anthropocentric focus toward a more ecological viewpoint, highlighting the interconnectedness and importance of diverse life forms in design and data interpretation.

9.4. "Shit! towards an experimental multiple-perspective approach to human-microbiome relations" by Danielle Wilde & Tau Lenskjold

In their article "Shit! Towards an experimental multiple-perspective approach to human-microbiome relations," Danielle Wilde and Tau Lenskjold (this volume) argue that rather than developing design research methods anew, inquiring into and experimenting with the workshop as an established design method in HCI can help designers move beyond human exceptionalism and embrace more-than-humans, such as multispecies assemblages and events. The article traces the history of workshops in HCI and Participatory Design and explores how workshops can be adapted for more-than-human design inquiries. By focusing on an experimental research project named Shit!, which explores the relationship between individuals with intestinal dysbiosis and their gut microbiome, the authors reflect on the challenges and potentials of conducting intimate, more-than-human design research in workshop settings, emphasizing collaborative and facilitated activities. As future directions, they propose self-experimentation kits as a way to rearticulate workshops to embrace situated knowledges and embrace diverse voices, perspectives, and species.

9.5. "What mosses can teach us about design fabulations and feminist more-than-human care" by Marie Louise Juul Søndergaard

In her article "What mosses can teach us about design fabulations and feminist more-than-human care," Marie Louise Juul Søndergaard (this volume) talks about the filming of"I Moss You," a short recorded through a microscope. The film tells a story about mosses and menses, space travel and earthly survival, which involves nonhumans in the speculative storytelling. In her account of the production of this fabulation as expression of a research-through-design practice, the author interweaves feminist and posthumanist design scholarship to challenge dominant sociotechnical imaginaries of progress and norms of technology. Through her fabulation, Marie Louise explores how feminist theory and values are core to posthumanist HCI, and how they can support more-than-human designers and researchers in questioning what is being decentered and what marginalized voices are foregrounded. By promoting feminist values such as situated knowledges and a relational becoming with ecology, fabulation is here offered as a feminist practice for more-than-human design.

9.6. "'Breathing-with:' a design tactic for the more-than-human" by Jonas Fritsch, Vasiliki Tsaknaki, Stina Hasse Jørgensen and Karin Ryding

In their article "'Breathing-with:' A design tactic for the more-than-human," Jonas Fritsch, Vasiliki Tsaknaki, Stina Hasse Jørgensen and Karin Ryding (this volume) focus on breath and breathing as a way to explore the relationality between human and non-human bodies. The work is empirically grounded in three design projects conducted between 2020 and 2022. By reflecting on how concrete design tactics were cultivated in these projects that extend the notion of the body in design processes toward the more-than-human, the authors extend the current repertoire of actions for designing with the more-than-human. In this context, "breathing-with" is a generative design tactic for zooming in and out of the entangled relationships between human and more-than-human bodies. As an action for designing with the more-than-human, deeply rooted in posthuman feminism, "breathing-with" surfaces the intimacy and vulnerability of human-nonhuman relations. As a tactic, "breathing-with" is also a counter-political and activist project that surfaces practices for sharing the resources we produce in an egalitarian manner.

9.7. "Decentering through design: tracing posthuman theory and practices in HCI" by Iohanna Nicenboim, Doenja Oogjes, Heidi Biggs and Seowoo Nam

In their article "Decentering through design: Tracing posthuman theory and practices in HCI" Iohanna Nicenboim, Doenja Oogjes, Heidi Biggs, and Seowoo Nam (this volume) use the notion of decentering as a starting point to unpack what a posthumanist reorientation in design might entail concerning theory and practice. Conceptually, 'decentering' offers several challenges as it questions the central role of human experience as a foundation for design practice. Mapping first what notions of decentering have come to emerge in theoretical discourse, and then how these have been picked up and used in HCI and design, the paper proposes five dimensions for articulating more-than-human design practices: "cornerstone," "crux," "constitution," "context," and "contribution." Looking across examples from their design practices, the authors move on to explore what these five dimensions bring to our understanding of decentering, and to what extent they are not only descriptive but also can become generative. Drawing upon the insights gathered, the paper proceeds to delineate a strategy in answer to Braidotti's (2019) appeal to materialize posthuman theory, emphasizing the idea of "decentering through design." As such, the paper challenges a relation to theory as something to be applied or used in design. Instead, it strives for a generative space that exists between theory and practice when articulating design processes.

9.8. "Productive oscillation as a strategy for doing more-than-human design research" by Joseph Lindley, Jesse Josua Benjamin, David Philip Green, Glenn McGarry, Franziska Pilling, Laura Dudek, Andy Crabtree, and Paul Coulton

In their article "Productive oscillation as a strategy for doing more-than-human design research," Joseph Lindley and colleagues (this volume) seek a synergy between design research and more-than-human inquiry. Their provocation is that posthuman theory is not merely something from which designers draw by importing knowledge from other fields of scholarship; it is also something designers generate as they conduct more-than-human design research in practice. Through the murky mechanics of abductive reasoning, the authors look back at their research through design practice to build an argument for the notion of "productive oscillation." The provocation of Lindley and colleagues is that "productive oscillation" is an emancipatory strategy that designers can adopt for side-stepping theoretical inconsistencies and taking advantage of multiple more-than-human theories within a single project. The authors contend that although there exists a plethora of specialized terminologies within more-than-human design, there are instances where it might be advantageous to incorporate concepts from various theoretical frameworks rather than fixating on the minutiae of their distinctions.

9.9. "The everyday enactment of interfaces: a study of crises and conflicts in the more-than-human home" by Evert van Beek, Elisa Giaccardi, Stella Boess, and Alessandro Bozzon

In their article "The everyday enactment of interfaces: A study of crises and conflicts in the more-than-human home," Evert van Beek, Elisa Giaccardi, Stella Boess, and Alessandro Bozzon (this volume) use a shift in how we conceive of interfaces from static touchpoints to something that is continuously enacted to explore how more-than-human orientations can alter our understanding of the interactions taking place in smart homes. Instead of aiming for convenience, simplicity and other qualities of technologies that quietly reside in the background, their approach begins with notions of co-performance, and where notions of appropriate – rather than automatic – action become central in everyday life. Building on an ethnographic study, the paper analyzes crises and conflicts occurring in everyday practices related to sustainability and energy use. Revisiting ideas often found in the design of smart home technologies, the paper argues that there are strong reasons for not always seeking to resolve tensions by making interaction smoother and technologies more proactive in relation to human needs and desires. Instead, they conclude that opening up for negotiation and for humans and non-humans to actively respond to each other offer important alternatives.

9.10. "The aesthetics of more-than-human design: speculative energy briefs for the chthulucene" by Alex Wilkie & Mike Michael

In their article "The aesthetics of more-than-human design: Speculative energy briefs for the Chthulucene," Alex Wilkie and Mike Michael (this volume) explore the potential of the design brief when shifting toward more-than-human design practices to reflect on how design might support reductions in energy-demand, and thus intervene in a complex system of human and non-human agencies. Unpacking the notion of the design event, and the design brief as part of it, the paper addresses fundamental aesthetical issues in how more-than-human elements of design – and the relations between them – can become present in design. Further unpacking what this might be like in practice, the paper describes a set of speculative design briefs in the context of design for reduced energy consumption, in which the notion of the "idiotic" (that is, that which does not make sense) plays a central role in opening up for the disorienting, the playful and ambiguous, thereby destabilizing prevalent modes of thinking and doing design.

10. Closing invitation

When introducing this special issue, we have chosen to focus on the research trajectories evident in the work presented here rather than what results they produce. And while this might suggest ongoing development, there are multiple reasons, beyond being only halfway, to maintain an open mind about what this emerging research field will yield. One such set of reasons formed the basis for this introductory text, namely the questions we can ask when watching a field grow, concepts being made and remade as scholars seek new practice as alternatives to existing ones. We used such questions to probe into how the presented works intersect with posthumanism and ideas of more-than-human, as well as existing HCI and design discourse, aiming to highlight trajectories and potentials.

As we now invite the readers of this journal to further explore this work, and see for themselves what is in the making here, there is, however, another set of reasons for keeping an open mind about where this might lead. Since its inception, industrial design as we now know it today has been propelled by the agendas inherent to industry, machinery, and the genuine and manufactured needs and desires of individuals (e.g., Fry et al., 2015). In many ways, user-centered design emerged as a response to such agendas, and in many cases from a need to defend the human in an otherwise often dehumanizing context (e.g., Cooper & Bowers, 1995). In light of the strong inclinations these orientations foster in how we think and do design, the idea of "more-than-human" not only suggests that design must pivot toward more inclusive, equitable, and sustainable futures, but also indicates a fundamental shift in the terrain we presently occupy. It suggests that the human-centric focus we've diligently cultivated is actually also problematic. Questioning one's foundations is no simple task.

Whether one agrees with the approaches advocated here or not, we argue that this opportunity to reflect upon what others are finding out as their foundations shift is interesting and important in itself. Just as the emerging field of industrial design sought alternative practices to traditional craft in response to a changing social and technological environment about a century ago, it is increasingly clear that new directions are needed yet again, if we are to respond to our contemporary societal, ecological and technological challenges. The question now is how to proceed – and the following are some suggestions on where to begin the search.

Disclosure statement

Funding

Notes on contributors

Elisa Giaccardi is an interaction design researcher working at the intersection of design, technology, and human transformation; formerly Professor in Post-industrial Design at Delft University of Technology, she is now Professor in More-than-human Design at Politecnico di Milano, Italy.

Johan Redström is a design researcher working at the intersections and interactions between research through design and design philosophy; he is Professor in Design at Umeå Institute of Design, Sweden.

Iohanna Nicenboim is an interaction designer and HCI researcher, focusing on more-than-human design practices across biology and AI technology; she is a Postdoctoral Fellow at Delft University of Technology, The Netherlands.

ORCID

Elisa Giaccardi 🟢 http://orcid.org/0000-0002-3292-2531
Iohanna Nicenboim 🟢 http://orcid.org/0000-0002-8363-8282

References

Bannon, L., & Schmidt, K. (1989). CSCW - Four characters in search of a context. *DAIMI Report Series*, *18*(289). https://doi.org/10.7146/dpb.v18i289.6667

Barad, K. (2003). Posthumanist performativity: Toward an understanding of how matter comes to matter. *Signs: Journal of Women in Culture and Society*, *28*(3), 801–831. https://doi.org/10.1086/345321

Barad, K. (2007). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Duke University Press.

Bardzell, S. (2010). Feminist HCI: Taking stock and outlining an agenda for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. 1301–1310). New York, NY, USA.

Bennett, J. (2010). *Vibrant matter: A political ecology of things*. Duke University Press.

Biggs, H. R., Bardzell, J., & Bardzell, S. (2021). Watching myself watching birds: Abjection, ecological thinking, and posthuman design. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery (pp. 1–16). New York, NY, USA.

Biggs, H. R., & Desjardins, A. (2020). High water pants: Designing embodied environmental speculation. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. 1–13). New York, NY, USA.

Bødker, S., Dindler, C., Iversen, O. S., & Smith, R. C. (2022). *Participatory design*. Springer.

Braidotti, R. (2019). *Posthuman knowledge* (1st ed.). Polity.

Cooper, G., & Bowers, J. (1995). Representing the user: Notes on the disciplinary rhetoric of human-computer interaction. In P.J. Thomas (Ed.), *The social and interactional dimension of human-computer interfaces*. Cambridge University Press.

Coskun, A., Cila, N., Nicenboim, I., Frauenberger, C., Wakkary, R., Hassenzahl, M., Mancini, C., Giaccardi, E., & Forlano, L. (2022). More-than-human concepts, methodologies, and practices in HCI. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems*, New York, NY: ACM. Article Article 150.

Coulton, P., & Lindley, J. G. (2019). More-than human centred design: Considering other things. *The Design Journal*, *22*(4), 463–481. https://doi.org/10.1080/14606925.2019.1614320

Deleuze, G. (2001). *Difference and repetition*. The Athlone Press.

Desjardins, A., Psarra, A., & Whiting, B. (2021). Voices and voids: Subverting voice assistant systems through performative experiments. *Proceedings of the 13th Conference on Creativity and Cognition*. Association for Computing Machinery (pp. 1–10, New York, NY, USA.

Devendorf, L., & Ryokai, K. (2015). Being the machine: Reconfiguring agency and control in hybrid fabrication. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. 2477–2486). New York, NY, USA.

Dew, K., & Rosner, D. (2018). Lessons from the woodshop: Cultivating design with living materials. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. 1–12). New York, NY, USA.

Dolejšová, M., Wilde, D., Altarriba Bertran, F., & Davis, H. (2020). Disrupting (more-than-) human-food interaction: Experimental design, tangibles and food-tech futures. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference. Association for Computing Machinery* (pp. 993–1004). New York, NY, USA.

Dourish, P. (2001). *Where the action is: The foundations of embodied interaction*. The MIT Press.

Forlano, L. (2017). Posthumanism and design. *She Ji: The Journal of Design, Economics, and Innovation*, *3*(1), 16–29. https://doi.org/10.1016/j.sheji.2017.08.001

Forlano, L. (2023). Living intimately with machines: Can AI be disabled? *Interactions*, *30*(1), 24–29. https://doi.org/10.1145/3572808

Foster, H. (2002). *Design and crime: And other diatribes*. Verso.

Frauenberger, C. (2019). Entanglement HCI the next wave? *ACM Transactions on Computer-Human Interaction*, *27*(1), 1–27. https://doi.org/10.1145/3364998

French, F., Mancini, C., & Sharp, H. (2020). More than human aesthetics: Interactive enrichment for elephants. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference. Association for Computing Machinery* (pp. 1661–1672). New York, NY, USA.

Fry, T., Dilnot, C., & Stewart, S. C. (2015). *Design and the question of history*. Bloomsbury.

Giaccardi, E. (2020). Casting things as partners in design: Towards a more-than-human design practice. In H. Wiltse (Ed.), *Relating to things: Design, technology and the artificial*. Bloomsbury (pp. 99–132).

Giaccardi, E., Cila, N., Speed, C., & Caldwell, M. (2016). Thing ethnography: Doing design research with Non-Humans. Proceedings of the 2016 ACM Conference on Designing Interactive Systems (DIS '16). Association for Computing Machinery, New York, NY, USA (pp. 377–387). https://doi.org/10.1145/2901790.2901905

Giaccardi, E., & Karana, E. (2015). Foundations of materials experience: An approach for HCI. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. 2447–2456). New York, NY, USA.

Giaccardi, E., & Redström, J. (2020). Technology and more-than-human design. *Design Issues*, *36*(4), 33–44. https://doi.org/10.1162/desi_a_00612

Grosz, E., & Stirner, S. (2016). All too human. *Qui Parle*, *25*(1–2), 17–33. https://doi.org/10.5250/quiparle.25.1-2.0017

Grudin, J. (1994). CSCW: History and focus. *IEEE Computer Society*, *27*(5), 19–26. https://doi.org/10.1109/2.291294

Haraway, D. (1991). *Simians, cyborgs, and women: The reinvention of nature*. Routledge.

Haraway, D. (2016). *Staying with the trouble: Making kin in the chthulucene*. Duke University Press.

Hayles, K. N. (1999). *How we became posthuman: Virtual bodies in cybernetics, literature, and informatics*. University of Chicago Press.

Hodder, I. (2012). *Entangled: An archaeology of the relationships between humans and things* (1st ed.). Wiley-Blackwell.

Kuijer, L., & Giaccardi, E. (2018). Co-performance: Conceptualizing the role of artificial agency in the design of everyday life. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* (pp. :125:1–:125:13). New York, NY, USA.

Lindley, J., Coulton, P., & Akmal, H. A. (2018). Turning philosophy with a speculative lathe: Object-oriented ontology, carpentry, and design fiction. In C. Storni, K. Leahy, M. McMahon, P. Lloyd, & E. Bohemia (Eds.), *Design as a catalyst for change – DRS International Conference 2018*, 25–28 June, Limerick, Ireland.

Liu, J., Byrne, D., & Devendorf, L. (2018). Design for collaborative survival: An inquiry into human-fungi relationships. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* New York, NY, USA. Article Paper 40.

Liu, S., Liu, J., Dew, K., Zdziarska, P., Livio, M., & Bardzell, S. (2019). Exploring noticing as method in design research. In *Companion Publication of the 2019 on Designing Interactive Systems Conference 2019 Companion*. Association for Computing Machinery (pp. 377–380). New York, NY, USA.

Mancini, C. (2017). Towards an animal-centred ethics for animal–computer interaction. *International Journal of Human-Computer Studies*, *98*(C), 221–233. https://doi.org/10.1016/j.ijhcs.2016.04.008

Murray-Rust, D., Gorkovenko, K., Burnett, D., & Richards, D. (2019). Entangled ethnography: Towards a collective future understanding. Proceedings of the Halfway to the Future Symposium 2019 (HTTF 2019). Association for Computing Machinery, New York, NY, USA, Article (Vol. 21. pp. 1–10). https://doi.org/10.1145/3363384.3363405

Nicenboim, I., Giaccardi, E., & Redström, J. (2023). Designing more-than-human AI: Experiments on situated conversations and silences. *Diid — Disegno Industriale Industrial Design*, *80*, 12–12. https://doi.org/10.30682/diid8023c

Nicenboim, I., Giaccardi, E., Søndergaard, M. L. J., Reddy, A. V., Strengers, Y., Pierce, J., & Redström, J. (2020). More-than-human design and AI. In *Conversation with Agents. Companion Publication of the 2020 ACM Designing Interactive Systems Conference*. (pp. 397–400). Association for Computing Machinery, New York, NY, USA.

Ofer, N., Bell, F., & Alistar, M. (2021). Designing direct interactions with bioluminescent algae. In *Proceedings of the 2021 ACM Designing Interactive Systems Conference 2021. Association for Computing Machinery* (pp. 1230–1241). New York, NY, USA.

Oogjes, D., & Wakkary, R. (2022). Weaving stories: Toward repertoires for designing things. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems. Association for Computing Machinery* New York, NY, USA. Article Article 98.

Orlikowski, W. J. (2007). Sociomaterial practices: Exploring technology at work. *Organization Studies*, *28*(9), 1435–1448. https://doi.org/10.1177/0170840607081138

Reddy, A., Nicenboim, I., Pierce, J., & Giaccardi, E. (2020). Encountering ethics through design: A workshop with nonhuman participants. *AI & Society*, *36*(3), 853–861. https://doi.org/10.1007/s00146-020-01088-7

Redström, J. (2020). Certain uncertainties and the design of design education. *She Ji: The Journal of Design, Economics, and Innovation*, *6*(1), 83–100. https://doi.org/10.1016/j.sheji.2020.02.001

Redström, J., & Wiltse, H. (2018). *Changing things: The future of objects in a digital world*. Bloomsbury.

Rosner, D. K. (2020). *Critical fabulations*. The MIT Press.

Shuler, D., & Namioka, A. (1993). *Participatory design: Principles and practices*. Routledge.

Tironi, M., Chilet, M., Marín, C. U., & Hermansen, P. (Ed.). (2023). *Design for more-than-human futures: Towards Post-Anthropocentric Worlding*. Routledge.

Tlostanova, M. (2021). Unlearning and relearning design. In T. Fry & A. Nocek (Ed.), *Design in crisis: New worlds, philosophies and practices* (pp. 163–180). Routledge.

Tomico, O., Wakkary, R., & Andersen, K. (2023). Living-with and designing-with plants. *Interactions*, *30*(1), 30–34. https://doi.org/10.1145/3571589

Treusch, P., Berger, A., & Rosner, D. K. (2020). Useful uselessness? Teaching robots to knit with humans. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference. Association for Computing Machinery* (pp. 193–203). New York, NY, USA.

Wakkary, R. (2021). *Things we could design: For more than human-centered worlds.* The MIT Press.

Wakkary, R., Oogjes, D., Hauser, S., Lin, H., Cao, C., Ma, L., & Duel, T. (2017). Morse Things: A design inquiry into the gap between Things and us. In *Proceedings of the 2017 Conference on Designing Interactive Systems. Association for Computing Machinery* (pp. 503–514), New York, NY, USA.

Westerlaken, M., Gabrys, J., Urzedo, D., & Ritts, M. (2022). Unsettling participation by foregrounding more-than-human relations in digital forests. *Environmental Humanities*, *15*(1), 87–108. https://doi.org/10.1215/22011919-10216173

Wilde, D., Dolejsova, M., van Gaalen, S., Altarriba Bertran, F., Davis, H., & Raven, P. G. (2021). Troubling the impact of food future imaginaries. In E. Brandt, T. Markussen, E. Berglund, G. Julier, & P. Linde (Eds.), *Nordes 2021: Matters of scale* (pp. 15–18). August, Kolding, Denmark. https://doi.org/10.21606/nordes.2021.10

Yoo, D., Bekker, T., Dalsgaard, P., Eriksson, E., Fougt, S. S., Frauenberger, C., Friedman, B., Giaccardi, E., Hansen, A.-M., Light, A., Nilsson, E. M., Wakkary, R., & Wiberg, M. (2023). More-than-human perspectives and values in human-computer interaction. In *Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems* (p. 5).

Zhou, J., Kim, R., Doubrovski, Z., Martins, J., Giaccardi, E., & Karana, E. (2023). Cyano-chromic interface: Aligning human-microbe temporalities towards noticing and attending to living artefacts. In *Proceedings of the 2023 ACM Designing Interactive Systems Conference. Association for Computing Machinery* (pp. 820–838). New York, NY, USA.