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Designing materials with living organisms for care-based practices: an analysis of case studies within the wearables domain

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Abstract: The unsustainable patterns of human consumption, exacerbated by materialism, digital technologies, disruptive global events and the mounting issue of e-waste, demand a fundamental shift in design approaches. In light of these challenges, this paper discusses how integrating living organisms into materials design can facilitate this transition, fostering innovative interactions and enabling care-based practices. By analysing three case studies in interaction design, the research highlights the transformative potential of incorporating biological matter like plants, moulds, bacteria and fungi into domains such as the one of wearables. The biodesign processes examined reveal commonalities, including the unpredictable, transient and time-consuming nature of designing with living organisms, as well as the evolving commitment and sensitivity of both designers and users towards the artefacts. The findings suggest that embracing non-human agency in the design field can nurture empathy and symbiosis and encourage users' ethical practices, responsibility, and emotional awareness. The study provides valuable insights into embedding care in design, redirecting the focus away from the traditional environmental products' durability to a designed temporality, capable of engendering long-term emotional durability.

Introduction

The contemporary world is marked by a rise in materialism, the pervasiveness of digital technology and the occurrence of significant global events. These phenomena represent a reflection of humans' profound impact on the Earth. Current production and consumption patterns reveal a lifestyle that is no longer sustainable for the ecosystem (Bocken & Short, 2021; Schor, 2005), with everyday goods representing biodiversity threats due to poor material decomposability or improper disposal practices.
Among many other products, electronic devices contribute significantly to these impacts, representing a growing market (Forti et al., 2020) unfortunately designed for obsolescence. E-waste, containing both harmful and valuable components, requires specialised recycling methods to mitigate environmental damage (Grant et al., 2013; He et al., 2024; Robinson, 2009).

Given these patterns of human consumption, a system that eliminates pollution and maintains the circulation of materials is now imperative (Ellen MacArthur Foundation, n.d.). The materials design field can lead this transition of paradigm from consumerism towards responsible systems (Duarte Poblete et al., 2024). From this perspective, designers should look beyond the products' environmental lifespan and disposability. They should also recognise the dynamic nature of matter (Bennett, 2010) and explore new approaches to enhance its emotional and communicative value. By activating attachment to objects, designers can overcome the utilitarian sense of sustainable materials and embrace the concept of artefacts as bearers of meanings that the consumers convey (Chapman, 2009). Such a shift in a designer's mindset could facilitate a transformation in the user's engagement, thereby fostering virtuous behaviours. Consequently, designers should grasp strategies to implement durability at two levels, focusing on the materials' environmental impact and the sensorial experience and emotional responses they evoke (Karana et al., 2015).

Recently, several academics have been experimenting with the integration of living organisms to accomplish this goal, featuring "unique functionalities" (Karana et al., 2020) and mechanisms to change user-product interactions (Kim et al., 2023; Moisy & Pschetz,

2017; Pataranutaporn et al., 2020). In the design field, this emerging approach – incorporating biological matter into materials, processes, and tools – is referred to as biodesign (Myers, 2012).

The paper aims to delineate the potential of integrating living organisms into design as a means of fostering transformative change through innovative care-based practices. Using a case study methodology of wearables projects situated at the nexus of biodesign, materials design, and interaction design, the authors posit that including a non-human perspective in artefacts may promote the emergence of novel avenues that move from traditional products' durability to a designed temporality comprising interactions that may foster emotional durability over the long term.

Living Materials and Potentialities: when care shapes product durability

Biodesign represents an interdisciplinary design practice that integrates biological knowledge with design principles by incorporating organisms, such as algae, bacteria, fungi, plants and moulds. By feeling, growing, regenerating, adapting, and decaying, living components impart design artefacts with a material quality defined as "livingness" (Karana et al., 2020).

The speculative and pioneering nature of biodesign is based on methods like biofabrication, coming for biomedical applications and generating complex biological products of living and non-living matter (Mironov et al., 2009). These processes demand minimal energy inputs and generate biodegradable materials, aligning with environmental implementations and closed-loop systems essential in the present era (Camere & Karana, 2018). However, living artefacts extend beyond the realms of sustainability and circularity, fostering a holistic and renewable perspective that overcomes the duality between humans and nature (Cole, 2012) and promotes regenerative ecologies (Karana et al., 2023).

The intricate relationship established in integrating living organisms into materials transcends the boundaries of typical interactions, involving a post-humanist, "more-than-human" perspective (Tarcan et al., 2022). The concept of "designing with" living organisms marks a significant shift in the traditional, centralised design approach in which humans are the primary agents of change (Tomico et al., 2023). This transition – affecting not only designers but also users – towards an interrelationship between "cooperators" (Pinto et al., 2013) compels the adoption of participatory actions (Ooms et al., 2022). Within this framework, non-humans act as co-performers in shaping the scope of design and co-creating futures (Giaccardi, 2020) through behavioural constructs such as "collaborative survival" (Karana et al., 2023) or "symbiosis" (van den Broek et al., 2022).

A foundational concept underlying biodesign and, more in general, More-than-Human design (MtHD) is that of "mutualistic care," outlined as "a reciprocal and evolving relationship between humans and living artefacts" (Karana et al., 2020). The human being, in this context, embodies the subject of affective concern and the one who benefits from it, thereby assuming the roles of both "caregiver" and "care receiver" (van den Broek et al., 2022). Amongst several studies on the topic (Chen et al., 2021; Key et al., 2021; Ooms et al., 2022), Lu and Lopes (2022) reflect on the concept of "care-based interactions" and how integrating living organisms into interactive devices alters the user-interface relationship. Unlike conventional electronics that embed living organisms solely for functional purposes, their work elucidates the biological potential for sustainable interactions and deeper material considerations.

Through concrete examples and speculative theories, de la Bellacasa (2017) shows how care can be instrumentalised to become a transformative practice capable of redefining ways of living and interacting with technological and natural worlds. Similarly, Mattern (2018) suggests that care can serve as a crucial lever that "practitioners who design our material world" – together with policymakers and citizens – could use to construct equitable, responsible systems. Additionally, Moriggi and colleagues (2020) identify three main dimensions of care – "ethically-informed practices", "relational response-ability", and "emotional awareness" – which they propose can reframe human power and establish interdependence between subjects. Hence, they prove the potential of caring practices by

developing "interactivities" that instruct individuals to act consciously and challenge unethical behaviour. Thus, the notion of care in MtHD extends beyond human-centred empathy, encompassing an ethical and political commitment to non-human entities as well.

Methodology

Founded on a constructivist epistemological position, the paper employs a case study methodology – a research strategy comprehending qualitative tools like logical design, data collection techniques and data analysis approaches (Creswell & Creswell, 2017; Yin, 2006). More in detail, this study uses a comparative method on three cases from the wearables domain, guided by the following research question: ***Which specific features, activated through the integration of living organisms, can stimulate care-based practices and serve as catalysts for emotional durability?***

The selection of specific case studies is based on the application of clearly defined criteria. First, the cases are drawn from the field of interaction design and examine the same product properties to avoid substantial differences that could divert the focus of the study. Secondly, the case studies encompass a diverse range of living organisms and techniques to broaden the scope of evaluation. Additionally, each case study presents concrete outcomes and is accompanied by textual documentation, providing a comprehensive understanding of the design phases and analysis of users' perspectives. At last, the cases are subjected to an initial overview of the projects' information and an examination of the specific aspects of each project to determine key common features characterising the process of interacting with living organisms.

FloraWear

FloraWear by Nam, Campbell, Webb and Harmon (2023) combines fashion and horticulture, encouraging personal interaction with plants and promoting biophilia. The designers propose a DIY approach, allowing users to select a desired shape (necklace, ring, or bracelet) and customise it through an open-source platform for 3D printing. Subsequently, customers can cultivate seeds of different species on the substrate, providing daily irrigation and monitoring. The wearable can be replanted and reused at the end of a plant's lifecycle, reinforcing sustainable and circular practices. The interviews resulting from the project reveal the presence of emotional bonds forged through the users' direct, embodied engagement with nurturing plants.

Slime mould smartwatch

This smartwatch, developed by Lu and Lopes (2022), incorporates the living slime mould species of *Physarum polycephalum* to challenge the conventional notions of interactive technologies. The wearable blends living and non-living components, using the slime mould as both a functional heart-rate sensor and a symbolic element. To maintain functionality, the slime mould requires regular care in the form of water and nutrients. Neglecting its upkeep, the organism enters a dormant state and effectively disables the smartwatch's sensing capabilities. Therefore, the integration of the living component into the device creates a unique symbiotic relationship between users and devices characterised by responsibility and empathy.

Loupe & Lightbox

This project by Boer, Bewley, Jenkins, Homewood, Almeida, and Vallgårda (2020) explores alternative gut health self-tracking technologies by challenging the embarrassment due to illness forms assessment and fostering a more intuitive and tangible understanding of wellness over time. The authors first collaborated with user experts on the gut-brain relationship, inspiring the design brief for the devices. These studies revealed that users could develop a nurturing relationship with their gut microbiota, viewing self-tracking as a form of cultivation rather than mere data collection. Therefore, the project led to the design of two devices: *Loupe*, a wearable viewer designed to externalise gut biota, allowing users to closely examine and aesthetically appreciate their microbiome; *Lightbox*, complementing the wearable as a support to observe the agar-based Petri dishes and reflect upon the cultivated gut bacteria, enhancing the user's engagement and understanding.

Results

The case studies examined showcase diverse approaches in integrating living organisms in artefacts at the convergence of biodesign,

materials design and interaction design, each prioritising sustainable and interactive material use.

What emerges from the initial analysis and comparison of these artefacts – summarised in Table 1 – is that *FloraWear* promotes the integration of living materials for biophilic connections through wearable forms, while *Loupe & Lightbox* reimagine self-tracking tools for the gut microbiome and related mental well-being as cultivation devices that foster long-term nurturing relationships. The *Slime mould smartwatch* goes beyond the previous wearables design, integrating the digital functionality of microorganisms to encourage tangible care.

Each project explores the dynamic behaviour of living organisms, with particular attention to the involvement of users. The three projects represent "wearable provotypes" (Chen et al., 2024) that – rather than focusing on market-driven devices – mediate human-nonhuman interactions, speculating on alternative materialities and activating high emotional connections through care and symbiosis.

All projects highlight iterative design methodologies, employing experimentation and documentation to ensure materials interact seamlessly with users. Furthermore, an overlapping theme across the cases is the need for a balance between material considerations, aesthetic appeal, and user engagement.

	FloraWear	**Slime mould smartwatch**	**Loupe & Lightbox**
Designers	Hye Yeon Nam, JaNiece Campbell, Andrew Webb & Brendan Harmon 	Jasmine Lu & Pedro Lopes 	Laurens Boer, Harvey Bewley, Tom Jenkins, Sarah Homewood, Teresa Almeida, & Anna Vallgårda 
Main living organisms and materials	Plants (*Arugula, Alfalfa, Amaranth, Basil, Bean, Beets, Broccoli, Chia, Chives, Cilantro, Kale, Mint, Parsley, Peppermint, Radish, Rosemary, Thyme, Sage, Wildflowers*)	Slime mould *(Physarum polycephalum)*	Gut Bacteria, (contingent) Fungi
Typology of wearables and functionality	Jewellery-like wearables (necklaces, bracelets and rings) with living plants for co-living	Smartwatch for heart-rate sensing	Necklace-like wearable viewer complemented with a lightbox
Projects objectives	Foster empathy and biophilia	Empower users through physical care/responsibility	Design an alternative gut self-tracking device for aesthetic appreciation and closer self-awareness
Methodology of materials interaction investigation	Experimentation; documentation; designers' material experience; user studies analysis (questionnaires and interviews)	Experimentation; documentation; technical evaluation; designers' material experience; user studies analysis (interviews and diaries)	Experimentation; documentation; technical evaluation; designers' material experience; user studies analysis (probes and reports)
Interaction level (designers)	High: *plant growth; substrate experimentation*	Medium: *laboratory-based exploration*	High: *bacteria exploration and growth; substrate experimentation with dyes*

Interaction level (users)	High: *sensorial connection; empathy; nurturing process*	High: *functional connection; sensorial connection; empathy; nurturing process*	High: *functional connection; sensorial connection; empathy; nurturing process*
Required care level	High: *daily watering of plants*	High: *regular feeding and hydration*	High: *regular monitoring and collection of bacteria*
Fabrication approaches, methods and techniques	DIY-bio approach; hybrid craft; biofabrication; material layering; horticulture; 3D printing	Laboratory development; 3D printing; material layering; electronics embedding	Laboratory development; DIY dying; hybrid craft; biofabrication; culturing; 3D printing
Sustainability and Longevity aspects	Compostability of plants; regeneration of plants; reusability of substrate	Reusability and recyclability of casing; regeneration of mould; reusability of electronics	Regeneration of bacteria; biodegradability and regeneration of agar substrates

Table 1. Overview of case studies. © All images are copyrighted by the respective authors of the works cited in this paper.

The second examination enabled the authors to correlate the procedural and emotional information provided in the designers' theoretical dissemination, determining the innovative characteristics implied in the integration of living materials into wearables. The resulting specific elements of each product can be traced back to more generic categories of emerging common features, emphasising the user interaction with livingness and the creation of care-based bonds. Hereafter, each feature is examined in correlation with emotional durability.

As visible in Table 2, materials' "growth duration" periods vary significantly, ranging from 30 days to continuous cycles. The emerging feature here is the **time-consuming nature** of the process. The actors involved experience various temporal scales in different ways. This could be perceived as either an investment of effort or a ritual of care, directly connecting to emotional durability by fostering attachment or annoyance (if the user is unwilling to commit time). Common "growth variabilities" include dependency on environmental conditions (e.g., temperature, light, humidity, gravity), internal conditions (e.g. user gut health) and user behaviour. This results in a variable evolution of the product generating curiosity and engagement but also uncertainty. Emotional durability here hinges on whether **unpredictability** is seen as exciting or overwhelming. The "challenges" associated with these wearables also include the organisms' responses to environmental factors and the risk of other microorganisms' contamination, leading to a **loss of control** by humans over the process. While this may cause anxiety, it also encourages the adoption of collaboration with living, intelligent agents. The "requirements" for maintaining these wearables involve constant upkeep and care efforts, which may induce the burden of worry, stress and attachment in the user. This fosters a **sense of responsibility** towards the wearables, enhancing emotional durability by strengthening the user-product bond. Additionally, "materiality and sustainability aspects" further reinforce this relationship by embracing organic textures, transformations from dormancy to activation, natural dyes, and biodegradability. These characteristics highlight the **imperfect and transient nature** of the product, shifting its perception from a static object to a living actor, which encourages users to accept change and evolution as part of the experience. "Use modes" involve repetitive refinements and continuous symbiosis between the user and the organism, reinforcing the emerging feature of **iterative and collaborative actions**. This makes the user an active cooperator, increasing emotional investment and attachment. Similarly, "innovative and unusual aspects" such as dormancy, growth, decay phases and changing behaviours require the user to develop **tolerance and acceptance** towards unfamiliar biological phenomena, further enriching emotional engagement. According to the willingness of the projects' designers, the "typology of connection" with the products is grounded in interactivities unlocked by livingness, transforming the wearable from a mere accessory into a companion. This aspect directly unlocks the emerging feature of **empathy and symbiotic attachment**. Finally, "interaction responses", as results of all the previously described aspects, encompass joy, stress, or frustration tied to the growth and decay of the organisms, with variable emotional reactions depending on the organism's success

or dormancy. The deriving **emotional fluctuations** enhance engagement but also introduce potential instability in user attachment.

These distinctive dimensions of integrating living organisms in products shift the design paradigms from inert to evolving and interactive experiences based on the care notion. In doing so, they support behaviours and practices in users that can serve as seeds for a future in which product durability extends beyond mere functionality and is also rooted in an emotional dimension.

	FloraWear	**Slime mould smartwatch**	**Loupe & Lightbox**	**Emerging shared features**
Growth duration	30 days (entire lifecycle)	Continuous (regular feeding and care)	Continuous (regular monitoring and care)	**Time-Consuming Process**
Growth variabilities	Health depends on user care and varies with external parameters (temperature, light, water, gravity, etc.)	Behaviour and durability depend on user care and vary with internal and external parameters (temperature, light, etc.)	Behaviour and durability depend on user care and vary with internal (user gut bacteria health) and external parameters (temperature, light, etc.)	**Unpredictability**
Challenges	Organisms' responses to environment; Micro-organisms contamination	Organisms' responses to environment; Micro-organisms contamination	Organisms' responses to environment; Micro-organisms contamination	**Loss of Control of the process**
Requirements	Management of standard external parameters; Maintenance; Care efforts; Sense of worry or stress	Management of standard external parameters; Maintenance; Care efforts; Sense of worry or stress	Management of standard external parameters; Maintenance of bacteria viability; Care efforts; Sense of worry or stress	**Sense of Responsibility**
Materiality and sustainability aspects	Organic shapes; Changes of matter from dormancy to activation; Biodegradability	Organic shapes and textures; Changes of matter from dormancy to activation	Organic shapes and textures; Natural dyes; Biodegradability	**Imperfect and Transient Nature**
Use modes	Repetition of actions to refine design; Plant care and co-living	Continuous symbiosis between user and organism	Repetition of actions to cultivate bacteria; Continuous symbiosis between user and organism	**Iterative and Collaborative Actions**
Innovative and unusual aspects	Dormancy, growth and decay phases	Slime mould's natural behaviour	Gut bacteria's direct visualisation and growth	**Tolerance and Acceptance**
Typology of connection with the product	Emotional bonds with plants through care	Symbiotic relationship through care	Nurturing relationship through care	**Empathy and Symbiotic Attachment**
Interaction responses	Joy, stress or frustration with plants' growth and decay	Variable feelings tied to the organism's success or dormancy	Variable feelings tied to gut-mental health and bacteria's aesthetic appearance	**Emotional Fluctuations**

Table 2. Analysis of cases' key aspects, highlighting the resulting shared traits of biodesign processes.

Discussion and Conclusions

This paper examines the potential of care in integrating living organisms, such as plants, bacteria, fungi and moulds, into design. Using a multiple-case analysis of three wearable projects at the intersection of biodesign, materials design, and interaction design, the study highlights how the inclusion of living organisms fosters innovative, caring interrelationships.

Drawing on Moriggi et al. (2020), the analysis findings can be traced back to the three pillars of care. Sustainability aspects, the sense of responsibility, the lack of control over the process and iterative and collaborative actions all contribute to shaping "ethically-informed practices" through interdependencies and commitment. Responsibility – together with empathy, symbiosis, emotional fluctuations and interactions – implies "relational response-ability", proving the ability to respond and adapt to other agents' needs. Moreover, as also observed by Pinto and colleagues (2013), the imperfection and transience of living artefacts act as catalysts for "spaces of feelings" while interacting with living organisms, supporting the third care-based dimension of "emotional awareness" (Moriggi et al., 2020).

The authors acknowledge the focus on experimental projects confined to the limited domain of wearables. Therefore, they recognise that the virtuous behaviours unlocked by living artefacts may not necessarily be conducive to sustainable and responsible transition. The mindful consideration of the traditional products' lifespans remains a decisive factor in design. However, this study can serve as an illustrative example to inform further research in other design domains.

Ultimately, this paper puts forward biodesign as an approach to materials design that serves as a stimulus to acknowledge the possibilities of more-than-human collaboration. The resulting intentional and transient interactions – eliciting empathy, cooperation and symbiosis – shift the focus away from traditional material durability towards a concept of designed temporality. Consequently, the insights encourage designers to embed care-based practices into products, paving the way for emotional durability in future production and consumption patterns.

References

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

Bocken, N. M. P. & Short, S. W. (2021). Unsustainable business models – Recognising and resolving institutionalised social and environmental harm. *Journal of Cleaner Production*, *312*, 127828. https://doi.org/10.1016/j.jclepro.2021.127828

Boer, L., Bewley, H., Jenkins, T., Homewood, S., Almeida, T. & Vallgårda, A. (2020). Gut-Tracking as Cultivation. *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, 561–574. https://doi.org/10.1145/3357236.3395588

Camere, S. & Karana, E. (2018). Fabricating materials from living organisms: An emerging design practice. *Journal of Cleaner Production*, *186*, 570–584. https://doi.org/10.1016/j.jclepro.2018.03.081

Chapman, J. (2009). Design for (Emotional) Durability. *Design Issues*, *25*(4), 29–35. https://doi.org/10.1162/desi.2009.25.4.29

Chen, D., Seong, Y. ah, Ogura, H., Mitani, Y., Sekiya, N. & Moriya, K. (2021). Nukabot: Design of Care for Human-Microbe Relationships. *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–7. https://doi.org/10.1145/3411763.3451605

Chen, S. N., Flanagan, P. & Akmal, H. A. (2024). Escaping Human Experience: An Entry into Otherness Through Wearable Technology. *ISEA 2024 - International Symposium on Electronic Art.*

Cole, R. J. (2012). Regenerative design and development: current theory and practice. *Building Research & Information*, *40*(1), 1–6. https://doi.org/10.1080/09613218.2012.617516

Creswell, J. W. & Creswell, J. D. (2017). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (5th ed.). SAGE Publications, Inc.

de la Bellacasa, M. P. (2017). *Matters of Care: Speculative Ethics in More than Human Worlds*. University of Minnesota Press.

Duarte Poblete, S. S., Romani, A. & Rognoli, V. (2024). Emerging materials for transition: A taxonomy proposal from a design perspective. *Sustainable Futures*, *7*, 100155. https://doi.org/10.1016/j.sftr.2024.100155

Ellen MacArthur Foundation. (n.d.). *Circular Economy Introduction. Overview*. Retrieved 29 November 2024, from https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview#principles

Forti, V., Baldé, C. P., Kuehr, R. & Bel, G. (2020). *The Global E-waste Monitor 2020. Quantities, flows, and the circular economy potential*. United Nations University (UNU)/United Nations Institute for Training and Research (UNITAR) – co-hosted SCYCLE Programme, International Telecommunication Union (ITU) & International Solid Waste Association (ISWA), Bonn/Geneva/Rotterdam. https://ewastemonitor.info/wp-content/uploads/2020/11/GEM_2020_def_july1_low.pdf

Giaccardi, E. (2020). Casting Things As Partners In Design: Toward A More-Than-Human Design Practice. In *Relating to Things* (pp. 99–132). Bloomsbury Publishing Plc. https://doi.org/10.5040/9781350124288.ch-006

Grant, K., Goldizen, F. C., Sly, P. D., Brune, M.N., Neira, M., van den Berg, M. & Norman, R. E. (2013). Health consequences of exposure to e-waste: a systematic review. *The Lancet Global Health*, *1*(6), e350–e361. https://doi.org/10.1016/S2214-109X(13)70101-3

He, Y., Kiehbadroudinezhad, M., Hosseinzadeh-Bandbafha, H., Gupta, V. K., Peng, W., Lam, S. S., Tabatabaei, M. & Aghbashlo, M. (2024). Driving sustainable circular economy in electronics: A comprehensive review on environmental life cycle assessment of e-waste recycling. *Environmental Pollution*, *342*, 123081. https://doi.org/10.1016/j.envpol.2023.123081

Karana, E., Barati, B. & Giaccardi, E. (2020). Living artefacts: Conceptualizing livingness as a material quality in everyday artefacts. *International Journal of Design*, *14*(3), 37-53.

Karana, E., McQuillan, H., Rognoli, V. & Giaccardi, E. (2023). Living artefacts for regenerative ecologies. *Research Directions: Biotechnology Design*, *1*, e16. https://doi.org/10.1017/btd.2023.10

Karana, E., Pedgley, O. & Rognoli, V. (2015). On Materials Experience. *Design Issues*, *31*(3), 16–27. https://doi.org/10.1162/DESI_a_00335

Key, C., Browne, F., Taylor, N. & Rogers, J. (2021). Proceed with Care: Reimagining Home IoT Through a Care Perspective. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, 1–15. https://doi.org/10.1145/3411764.3445602

Kim, R., Risseeuw, C., Groutars, E. G. & Karana, E. (2023). Surfacing Livingness in Microbial Displays. *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, 1–21. https://doi.org/10.1145/3544548.3581417

Lu, J. & Lopes, P. (2022). Integrating Living Organisms in Devices to Implement Care-based Interactions. *Proceedings of the 35th Annual ACM Symposium on User Interface Software and Technology*, 1–13. https://doi.org/10.1145/3526113.3545629

Mattern, S. (2018). Maintenance and Care. *Places Journal*. https://doi.org/10.22269/181120

Mironov, V., Trusk, T., Kasyanov, V., Little, S., Swaja, R. & Markwald, R. (2009). Biofabrication: a 21st century manufacturing paradigm. *Biofabrication*, *1*(2), 022001. https://doi.org/10.1088/1758-5082/1/2/022001

Moisy, A. & Pschetz, L. (2017). Designing with living organisms. *Proceedings of the 3rd Biennial Research through Design Conference RTD'17*, 323–339. https://doi.org/10.6084/m9.figshare.4746994.v1

Moriggi, A., Soini, K., Franklin, A. & Roep, D. (2020). A Care-Based Approach to Transformative Change: Ethically-Informed Practices, Relational Response-Ability & Emotional Awareness. *Ethics, Policy & Environment*, *23*(3), 281–298. https://doi.org/10.1080/21550085.2020.1848186

Myers, W. (2012). *Biodesign. Nature, Science, Creativity* (1st ed.). Thames & Hudson.

Nam, H. Y., Campbell, J., Webb, A. M. & Harmon, B. (2023). FloraWear: Wearable Living Interface. *Proceedings of the Seventeenth International Conference on Tangible, Embedded, and Embodied Interaction*, 1–15. https://doi.org/10.1145/3569009.3572801

Ooms, D., Barati, B., Bruns, M. & van Dongen, T. (2022). From Concern to Care: A Transformative Reflection on Designing-with the Living. *Nordic Human-Computer Interaction Conference*, 1–15. https://doi.org/10.1145/3546155.3547285

Pataranutaporn, P., Vujic, A., Kong, D. S., Maes, P. & Sra, M. (2020). Living Bits: Opportunities and Challenges for Integrating Living Microorganisms in Human-Computer Interaction. *Proceedings of the Augmented Humans International Conference*, 1–12. https://doi.org/10.1145/3384657.3384783

Pinto, R., Carvalhais, M. & Atkinson, P. (2013). Generative designing with biological systems - searching for production tools aimed at individualization. *Proceedings of the 10th European Academy of Design Conference 2013, Gothenburg.*

Robinson, B. H. (2009). E-waste: An assessment of global production and environmental impacts. *Science of The Total Environment*, *408*(2), 183–191. https://doi.org/10.1016/j.scitotenv.2009.09.044

Schor, J. B. (2005). Prices and quantities: Unsustainable consumption and the global economy. *Ecological Economics*, *55*(3), 309–320. https://doi.org/10.1016/j.ecolecon.2005.07.030

Tarcan, B., Pettersen, I. N. & Edwards, F. (2022). Making-with the environment through more-than-human design. In D. Lockton, S. Lenzi, P. Hekkert, A. Oak, J. Sádaba & P. Lloyd (Eds.), *DRS2022: Bilbao*. Design Research Society (DRS), 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.347

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

van den Broek, S., de Rooij, A. & van Dartel, M. (2022). Living with living artefacts: Six concepts for designing user acceptance of living artefacts. In D. Lockton, S. Lenzi, P. Hekkert, A. Oak, J. Sádaba & P. Lloyd (Eds.), *DRS2022: Bilbao*. Design Research Society (DRS), 25 June - 3 July, Bilbao, Spain. https://doi.org/10.21606/drs.2022.261

Yin, R. K. (2006). Case Study Methods. In J. L. Green, G. Camilli & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 111–122). Lawrence Erlbaum Associates Publishers.