Designing for Entangled Speculation:
A Research Through Design Approach for Exploring Wicked Problems

Michael W. Beach

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Tyler Fox, Chair

Jennifer Turns

Eben Kirksey

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Abstract

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Michael W. Beach

Chair of the Supervisory Committee:

Tyler Fox

Department of Human Centered Design and Engineering

This dissertation explores *entanglement* as a structuring logic for speculative engagement, aiming to unsettle dominant ontologies and epistemologies to and expand design practice toward the ethical demands of an entangled world. This approach matters because the wicked problems we face in the 21st century, such as climate crisis, social inequity, global health crises, and extractive infrastructures, resist tidy solutions and expose the limits of conventional design frameworks that rely on separability, linear causality, or predictable outcomes. Grasping the magnitude, scale, and complexity of these challenges remains to be understood and will require new methods, approaches, and practices that can hold contradiction, that can embrace the unknown, that can imagine pathways of transformation. Many fields, disciplines, and communities develop their own knowledge practices for creating and maintaining contributions of meaning and understanding of how our world is entangled, from social and ecological entanglements found in HCI, social science, anthropology, animal studies, multispecies justice,

critical geographies, law, art, and design, to the scale of entangled particles in quantum physics. By integrating insights of quantum mechanics with design speculation, this research acknowledges the world as it actually is: interconnected, uncertain, and deeply entangled. This dissertation presents *Designing for Entangled Speculation* (DES), a framework that integrates conceptual resources from quantum entanglement—*superposition, observer effect, interconnectedness,* and *nonlocality & nonlinearity*—to expand the theoretical and methodological capacity of design speculation. Using a modified Research through Design (RtD) approach, I conducted three investigations representing varied configurations of abstraction, situatedness, and stakeholder expertise. *Post(-)human Hazmat* explored speculative narrative as a means of interrogating multispecies relationality. *Speculative F/Actors: Climate Futures* operationalized collaborative material speculation to model climate-related system interactions. *Entangled Justice* convened practitioners and researchers with diverse expertise from domains including circular economy, marine energy, and climate migration to generate shared knowledge and ignorance maps through structured collaborative inquiry. A diffractive, cross-case analysis demonstrates how quantum entanglement concepts shape the dynamics of speculative engagement, influence participants' reasoning about complex systems, and foreground ethical and epistemic considerations within design processes. Together, these contributions position DES as an ethically attuned framework for opening design to more speculative and accountable engagements with the complexities of an entangled world.

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Dedication

To Erin, my amazing partner, whose steadiness, care, and belief in me carried this work through moments of doubt and momentum alike. This dissertation exists because of the life we built alongside it.

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Chapter 1: Introduction

> "There is absolutely no inevitability as long as there is a willingness to contemplate what is happening" – Marshall McLuhan

We are in a meaning-making situation of unintelligible events; our capacity is strained by events that defy linear causality or singular explanation. Climate change, for example, is a profoundly entangled crisis, one that traverses scales, species, systems, and generations. It is ecological and political, scientific and cultural, and inherently complex. It is a *wicked problem* (Rittel & Webber, 1973)[1], one that resists resolution and is deeply entangled with other wicked problems such as capitalism's extractive modes of labor and resource, colonial histories and their ongoing structural violences, racialized and uneven environmental degradation, forced migration and displacement, energy and housing injustice, and the erosion of shared realities in a world fractured by competing ideologies. Because of this complexity, no single design framing, whether human-centered, systems-oriented, speculative, or participatory, can fully capture the scope of what is at stake. Design's traditional tendency to isolate problems and pursue tidy solutions risks oversimplifying or even reinforcing the very conditions that make these problems so intractable. Since wicked problems require a multiplicity of approaches that can navigate these entanglements with care.

Design has always been speculative. As practitioners, we approach design work through our values, lived experience, and understanding of the world in order to change "existing situations into preferred ones."(Simon, 2019)[2] However, the act of *speculation is not neutral*. It never has been. Every product, system, and interface encodes an imagined future, shaping what it will enable, who it will serve, how it will endure. Yet, these futures are too often constrained by a narrow set of values: efficiency, scalability, optimization, and profitability. These are the ghosts of industrial logic, still haunting contemporary design practice, still shaping which futures are legible, which count as progress, and which are dismissed as impractical, irrational, or impossible. Thus, to engage in speculation is, by necessity, to navigate within these structures, but also to challenge and unsettle them, to imagine alternatives that resist extractive, deterministic, and linear modes of thought. The question is not whether design speculates, but whose futures it makes possible and whose futures it forecloses.

[1] Rittel, Horst WJ, and Melvin M. Webber. "Dilemmas in a general theory of planning." *Policy sciences* 4, no. 2 (1973): 155-169.
[2] Simon, Herbert A. *The Sciences of the Artificial*, reissue of the third edition. MIT press, 2019.

The speculative turn in design is not about introducing speculation where it was absent, but about exposing the speculative conditions already at work and expanding the possibilities of what design can become.

Designing for Entangled Speculation (DES)

This dissertation responds by developing a **Designing for Entangled Speculation (DES)** framework. Drawing from quantum entanglement principles, such as *superposition, observer effect, interconnectedness, and nonlocality & nonlinearity*, as conceptual tools, this dissertation explores how design speculation might operate as a mode of inquiry that rethinks foundational assumptions about separability, causality, and determinability in traditional design frameworks and imagines ontological reconfigurations as deeply interconnected and emergent, reshaping how we design in an entangled world.

These quantum entanglement principles describe a world that is not fixed or isolated, but relational and emergent. Design, too, can embrace this reality. It need not seek control or certainty where there is none, nor treat the future as a problem to be solved. Instead, design speculation can function as a reflexive and relational practice for engaging with the irreducible complexity of the world.

This dissertation draws inspiration from quantum concepts as generative orientations for design inquiry. I am not a physicist, and this work does not attempt to translate quantum theory in a technically precise way. Instead, it is grounded in a design practice inspired by play, experimentation, and the power of weirdness to open imaginative space.

> **RQ:** How might entanglement theory concepts expand design speculation in theory and practice?
> **RQ:** How do participants react to collaborative engagements that invite speculative engagement with wicked problems?

Overview of Investigations

Through a reflexive design practice using a Research through Design (RtD) approach, I designed three distinct workshops to engage with wicked problems with different degrees of speculative openness and contextual anchoring. The first, *Post(-)human Hazmat*, explored speculative abstraction as a way to unsettle human-centered assumptions and experiment with multispecies imaginaries. The second, *Speculative F/Actors: Climate Futures*, introduced a more structured approach to collective worldbuilding, creating space for strangers to build shared speculative futures around locally situated contexts. The third, *Entangled Justice*,

turned toward real-world contexts. Each session centered on a specific topic (circular economy, climate migration, or marine energy) and convened participants with domain expertise and lived experience related to those areas. Together, these three investigations provide a diverse set of data and artifacts that demonstrate entangled speculation across different contexts, showing how varying degrees of abstraction and situated engagement contribute to developing theory about *designing for entangled speculation*.

Contributions

This dissertation offers three major contributions: empirical, methodological, and theory-to-practice. Each contributes to the broader conversation in human-centered design, speculative practice, and justice-oriented research when design is reimagined through the conceptual framing of quantum entanglement.

Empirical Contributions

The empirical contributions of this dissertation include insights into how design practitioners and participants navigate complexity, relationality, and uncertainty within design interventions and wicked problems. Through three major investigations: (1) *Post(-)human Hazmat*, (2) *Speculative F/Actors*, and (3) *Entangled Justice*, this work documents how people make meaning together within speculative environments, and how their engagements shift based on the framing of the design space and activities (e.g., from abstract to grounded, open-ended to topic-specific).

The findings show that participants brought different epistemologies, histories, and investments into workshop spaces, and that the speculative designs they co-created were shaped by these situated knowledges. Rather than seeking consensus or resolution, participants learned to dwell within contradiction, temporal complexity, and entangled systems. These studies demonstrate the value of speculative design practices not as a tool for prediction or solutioneering, but as a context for relational engagement and ethical inquiry.

This work also contributes empirical insights into how speculative design can serve as a generative site for practicing climate justice across more-than-human relations, infrastructural imaginaries, and intergenerational concerns—especially when material realities and political stakes vary widely among participants.

Methodological Contributions

This dissertation contributes an iterative design workshop methodology for engaging with wicked problems through speculative and relational practices. Rather than applying a single framework across contexts, the methodology was reconfigured across studies—each becoming a site for methodological reflection and recalibration. The ability to shift between abstraction and contextual grounding became a methodological skill: a form of attunement to what each site required, and to the ethical, political, and material dimensions that emerged in each iteration.

Each workshop was also a methodological experiment in designing with principles of entanglement drawn from quantum theory—including superposition, observer effect, and nonlocality—as conceptual tools for cultivating different forms of responsiveness and co-presence. This approach expands participatory design by foregrounding uncertainty, partiality, and temporality not as limitations, but as generative conditions for ethical design inquiry.

The dissertation also contributes techniques for facilitating and analyzing speculative workshops that do not seek closure or consensus. These include techniques for supporting divergent worldbuilding, framing contradictory potentials as legitimate co-presences, and situating design within the lived and systemic realities of ecological and climate-related harm.

Rather than offering a generalizable toolkit or fixed methodology, this dissertation contributes a cultivated capacity for designing-with entanglement—an orientation that invites responsiveness to complexity, relationality, and situated conditions. The goal is not to resolve wicked problems through standardized solutions, but to develop practices that can stay with the trouble, move between abstraction and grounding, and open space for more just and plural futures to emerge.

Theory-to-Practice Contributions

The central theory-to-practice contribution of this dissertation is the development of entangled speculation—a design approach that integrates speculative inquiry with concepts from quantum mechanics and process philosophy to inform ethical and situated design practices. This includes translating abstract quantum principles (e.g., superposition, observer effect, interconnectedness, and nonlinearity & nonlocality) into generative design orientations that help designers stay with complexity rather than reduce or resolve it.

In particular, this work articulates how these concepts can guide the design of workshops, speculative prompts, and relational framings that respond to systemic injustices and the uneven distributions of harm and care across human and more-than-human systems. Rather than using speculation to imagine alternate futures from a position of neutrality, entangled speculation foregrounds situatedness, epistemic multiplicity, and ontological interdependence.

By bridging speculative design, participatory practice, and quantum-informed theory, this work contributes to efforts in HCI and design studies that seek more expansive and justice-attuned epistemologies. It also offers practical strategies for cultivating conditions where plural futures can be imagined, not as an escape from reality, but as a mode of engaging with it more critically, creatively, and relationally.

Limitations

This dissertation is situated in a particular set of contexts, practices, and positionalities, and its findings should be understood in light of several limitations.

First, the workshops and studies presented in this work were conducted within academic, artistic, and institutional research settings, often drawing participants who were already open to speculative, justice-oriented, or experimental approaches. As such, the engagements documented here may not represent how entangled speculation might unfold in different groups or environments. The generative tensions explored in the workshops benefited from participants' willingness to engage with uncertainty, contradiction, and nonlinearity, conditions that may not be equally welcomed or productive in all design cultures.

Second, the speculative framing of each investigation required active facilitation and interpretation. As the designer and researcher, I shaped not only the scaffolding for engagement but also the discursive environment in which meaning was made. This introduces a reflexive limitation: while my design choices were intentional and responsive, they also carry my own situated perspectives and assumptions, shaped by my commitments to posthumanist ethics, design justice, and speculative practice. The dissertation does not claim objectivity or universality, but rather embraces partiality as an epistemological stance.

Third, while this work draws on concepts from quantum theory, it does so in a metaphorical and methodological sense rather than a strictly scientific one. These concepts are used as lenses for rethinking design relationships and processes, not as empirical claims

about the physical world. This translation invites philosophical and interpretive richness but may also be seen as speculative or ungrounded by more empiricist disciplines.

Finally, the temporal and resource constraints of dissertation research limited the depth and duration of participant follow-up. While rich insights emerged during each workshop, longer-term engagement would have allowed for a deeper understanding of how speculative interventions influence participants' ongoing thought and action. Future work could explore how these methods might be integrated into sustained design processes, institutional change efforts, or community-driven action.

Despite these limitations, this dissertation offers a foundation for continued exploration of entangled speculation as a relational and responsive design practice, and invites others to adapt, critique, and expand this work across new contexts and communities.

Dissertation Structure

In **Chapter 1: Introduction,** I provide both preliminary framing and motivation for the dissertation. In **Chapter 2: Literature Review**, I provide a review of literature needed to support the following theoretical foundations. In **Chapters 3: Methods**, I present a high-level introduction to each investigation along with the methods used in each. For **Chapters 4–6: Investigations**, I present each investigation in depth as case studies and theory-building sites. Each investigation chapter includes its own set of findings and describes how I made use of the findings along with my own experience to shape the next investigation. In **Chapter 7: Approaches for Entangled Speculation**, I present a higher-level analysis of the findings across all three investigations and compile a set of approaches for engaging in entangled speculation. In the final chapter, **Chapter 8–9: Discussion and Conclusion**, I situate this work in the larger context of design education, the future of speculation, and end with a discussion of the overall limitations to my approach to this dissertation and provide future directions of the work.

Chapter 2: Literature Review

This chapter reviews the bodies of literature that shape the conceptual foundation of this dissertation and explains how each section contributes to my approach to entangled speculation. I begin with *Humans + Technology + Design* to outline foundational assumptions in human-centered design and human–technology relations. I next turn to *Speculation + Design* to trace the emergence of speculative design from discursive design and to explain why speculative practices matter for future visioning and alternative world-making. The following section, *Collaboration + Design*, examines design's efforts to expand participation and democratize knowledge production, and explores participatory design with more-than-human concerns. With these strands established, I introduce *Entanglement + Design* to show how relational, ecological, and more-than-human scholarship extends design's scope and provides conceptual grounding for my project. I then differentiate relational entanglement from quantum entanglement, elaborate the quantum concepts central to my framework, and explain how these concepts operate as orientations for speculative practice. The chapter closes with critiques of entanglement that contextualize its limitations and guide its careful use in design research. Together, these sections create a structured foundation for the entanglement-informed investigations and *Designing for Entangled Speculation* (DES) framework developed in subsequent chapters.

Humans + Technology + Design

Design has traditionally focused on understanding human behavior and prioritizing human values[3] to provide solutions that address human needs in areas such as safety[4], health[5], wellbeing[6], pleasure[7], learning[8], and convenience. In Human-Computer Interaction

[3] Friedman, Batya, and David G. Hendry. *Value Sensitive Design: Shaping Technology with Moral Imagination*. Mit Press, 2019.

[4] Nouwen, Marije, Maarten Van Mechelen, and Bieke Zaman. "A value sensitive design approach to parental software for young children." In *Proceedings of the 14th International Conference on Interaction Design and Children*, pp. 363-366. 2015.; Badillo-Urquiola, Karla, Chhaya Chouhan, Stevie Chancellor, Munmun De Choudhary, and Pamela Wisniewski. "Beyond parental control: designing adolescent online safety apps using value sensitive design." *Journal of adolescent research* 35, no. 1 (2020): 147-175.

[5] Rundo, Leonardo, Roberto Pirrone, Salvatore Vitabile, Evis Sala, and Orazio Gambino. "Recent advances of HCI in decision-making tasks for optimized clinical workflows and precision medicine." *Journal of biomedical informatics* 108 (2020): 103479.

[6] Blandford, Ann. "HCI for health and wellbeing: Challenges and opportunities." *International journal of human-computer studies* 131 (2019): 41-51.; Thieme, Anja, Madeline Balaam, Jayne Wallace, David Coyle, and Siân Lindley. "Designing wellbeing." In *Proceedings of the Designing Interactive Systems Conference*, pp. 789-790. 2012.

[7] Tanenbaum, Theresa Jean, Amanda M. Williams, Audrey Desjardins, and Karen Tanenbaum. "Democratizing technology: pleasure, utility and expressiveness in DIY and maker practice." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 2603-2612. 2013.

[8] Stephanidis, Constantine, Gavriel Salvendy, Margherita Antona, Jessie YC Chen, Jianming Dong, Vincent G. Duffy, Xiaowen Fang et al. "Seven HCI grand challenges." *International Journal of Human–Computer Interaction* 35, no. 14 (2019): 1229-1269.; Cohen, P. R., & Feigenbaum, E. A. (Eds.). (2014). The handbook of artificial intelligence (Vol. 3). Los Alto, CA: William Kaufmann.; Wang, K., & Nickerson, J. V. (2017). A literature review on individual creativity support systems. Computers in Human Behavior, 74, 139–151. doi:10.1016/j.chb.2017.04.035; Wang, Y. (2014). From information revolution to intelligence revolution: Big data science vs. intelligence science.

(HCI), design has become more human-centric in the past few decades, enabling better products and services that meet the needs of people with a more fleshed out lived experience. Through human-centered design (HCD), we can better understand the types of interactions people experience, the benefits and harms associated with the limitations and affordances in interactions, and how these relate to the day-to-day lives of people. In second- and third-wave HCI, human-centered approaches extend beyond the immediate aspects of user-technology interactions and engage with issues of social change and social justice. This shift to heterogenous understandings of human experience brought in a wave of methods that brought non designers into design engagements. In the 1970s, with growing concerns about the relation between people and technology, participation and joint decision-making became essential in work environments and the introduction of new technology.[9] This led to the rise of *participatory design*, the idea that "those affected by a design should have a say in the design process."[10] (Read more about this in the "Collaboration + Design" section below.) This shift to co-design created disruption and democratized design processes for people. However, the body of work on co-design with nonhumans is still quite sparse and co-design approaches alone are not suitable for creating a comprehensive understanding of the complex and interconnected relationships, power and justice, between humans and nonhumans in more-than-human worlds. While some have found success with HCD, its promise of success has not been uniformly realized. It can reinforce existing power structures and privilege certain groups over others, particularly those with more access to resources and social capital. And it may not account for cultural differences and preferences, leading to a homogenization of design that does not suit the needs of diverse populations.

Human-centered thinking may be part of the problem rather than the answer to our problems regarding climate change as it may prioritize myopic and short-term gains over long-term sustainability and ecological considerations. It may not fully consider the unintended consequences and ethical implications of technological advancements, such as the potential for misuse or harm to individuals and society as a whole. It may perpetuate the assumption that technology is always the best solution to problems, rather than considering alternative, non-technological solutions.[11] The pursuit of human progress has depleted or made extinct what is not human, contributing to climate change and species extinction.[12] These exploitative relationships with nonhuman species and materials lead us to question the ideal of human progress and perfection. We must remember that human

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Proceedings of the 13th IEEE International Conference on Cognitive Informatics & Cognitive Computing (ICCI* CC 2014) (pp. 3–5). London, UK: IEEE. doi: 10.1109/ICCI-CC.2014.6921432

[9] Simonsen, Jesper, and Toni Robertson. *Routledge International Handbook of Participatory Design*. Vol. 711. Routledge New York, 2013.

[10] Ehn, Pelle. "Participation in Design Things." In *Participatory Design Conference (PDC), Bloomington, Indiana, USA (2008)*, 92–101. ACM Digital Library, 2008.

[11] Baumer, Eric PS, and M. Six Silberman. "When the implication is not to design (technology)." In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 2271-2274. 2011.

[12] Dirzo, Rodolfo, Hillary S. Young, Mauro Galetti, Gerardo Ceballos, Nick J. B. Isaac, and Ben Collen. "Defaunation in the Anthropocene." *Science* 345 (July 25, 2014): 401–6. https://doi.org/10.1126/science.1251817.

agency is not autonomous, but rather exists alongside nonhuman actors with their own forms of agency.

Turning toward a more-than-human understanding of design reveals a clearer picture of our entanglement with nonhumans. The turn to the more-than-human shifts the focus away from human reasoning to situated, partial, and multiple ways of knowing. From a design perspective, this epistemological opening begs the question: What does it mean to design within more-than-human worlds?

Speculation + Design

> "Just as objects act as physical prostheses, they can also be deliberately designed as intellectual prostheses. This leads toward what we refer to as discursive design—a broad categorization where the primary design intention is not utilitarian in the typical sense but rather to communicate particular ideas and to rouse reflection."
>
> *Discursive Design: Critical, Speculative, and Alternative Things* (p. 7)[13]

Discursive design is a broad umbrella term that encapsulates non-normative design practice (e.g., critical design, speculative design, radical design, etc.). "While having differences of approach, instantiation, and effect, they all are unified in their concern for intellectual impact," leading to what Tharp and Tharp refer to as "goods for thinking."[14] With discursive design, designers deliberately and explicitly "encode meaning and evocative capacities into objects with the goal of 'saying' something about or to individuals and society," challenging norms, resulting in an exposure of "implicit and uncontrived values, attitudes, behavioral expectations, and beliefs." These efforts are to provoke reflection and change in culture.

Speculative design is a design approach that aims not to solve immediate problems or meet consumer needs but to provoke critical reflection, explore alternative futures, and challenge existing socio-technical systems. Unlike traditional, user-centered, or market-driven design, which focuses on efficiency, usability, and product-market fit, speculative design deliberately avoids offering practical solutions or commercially viable outcomes. Instead, it uses fictional, provocative, and often non-functional artifacts to open debate about the social, ethical, and political implications of emerging technologies (Auger, 2013).[15] The term gained prominence through the work of Anthony Dunne and Fiona Raby, who introduced "Critical Design" in the late 1990s and later formalized speculative design as a method of

[13] Tharp, Bruce M., and Stephanie M. Tharp, *Discursive Design: Critical, Speculative, and Alternative Things* (MIT Press, 2019). pp. 7.
[14] Tharp and Tharp. pp. 8.
[15] Auger, James. "Speculative design: crafting the speculation." *Digital Creativity* 24, no. 1 (2013): 11-35.

"designing for debate" in Speculative Everything, emphasizing its role in unsettling the present rather than predicting the future (Dunne & Raby, 2013).[16] This approach draws on traditions of conceptual art and radical architecture (e.g., Superstudio, Archigram), distinguishing itself through its refusal to conform to the solutionism of mainstream design and its use of "what if?" scenarios to surface hidden assumptions and systemic flaws (DiSalvo, 2012; Dunne & Raby, 2013).[17] As such, speculative design has emerged as a critical practice and a means to interrogate rather than affirm the status quo.

Expanding on this reflection to possible futures, speculative design semantically signals an emphasis on the difference between the present and the fictional world from which the design object originates,[18] making it amenable to considering ethical quandaries brought forth by climate change. As such, speculative practices help designers work against the limitations of conventional design practices such as design thinking and user-centered design.[19] Inspired by the Italian Radical Design movement of the 1970s and introduced in the earlier work of Dunne and Raby in the 1990s,[20] critical design serves as a counterpoint to affirmative design, which reinforces existing social, political, and economic norms.[21] Instead, critical design "provides a critique of the prevailing situation through designs that embody alternative social, cultural, technical or economic values."[22] Meanwhile, speculative design focuses on the future and its possibilities, critiquing and fostering discussions by emphasizing exploration and experimentation.[23] This fusion of critical and speculative design has led to a renewed interest in the field and in design programs that focus on reimagining the present and future, for example, the Transition Design program developed by Terry Irwin at Carnegie Mellon University.[24]

The *Transition Design* approach seeks to address "wicked" problems through processes of *reframing and mapping interdependencies, causal relationships, conflictual relationships, and affinities*.[25] This work is put in concert with *future visioning* techniques "such as 'design fiction,' 'speculative/critical design,' and 'experiential futures' that are concerned with

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[16] Dunne, Anthony, and Fiona Raby. *Speculative Everything, With a new preface by the authors: Design, Fiction, and Social Dreaming*. MIT press, 2024.
[17] DiSalvo, Carl. "FCJ-142 Spectacles and tropes: Speculative design and contemporary food cultures." *Why Food Matters: Critical Debates in Food Studies* 325 (2021).
[18] Auger, James. "Speculative Design: Crafting the Speculation," *Digital Creativity* 24, no. 1 (2013): 11–35.
[19] Iskander, N.: Design thinking is fundamentally conservative and preserves the status quo, in Harvard Business Review, 5. (2018)
[20] Dunne, Anthony, and Fiona Raby. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT press, 2013.; Malpass, Matt. *Critical Design in Context: History, Theory, and Practice*. Bloomsbury Publishing, 2019.
[21] Dunne, Anthony, and Fiona Raby. *Design noir: The secret life of electronic objects*. Springer Science & Business Media, 2001.
[22] Dunne and Raby. *Design noir: The secret life of electronic objects*. 2001 (p.58)
[23] DiSalvo, Carl, and Jonathan Lukens. "Towards a critical technological fluency: The confluence of speculative design and community technology programs." (2009).
[24] Irwin, Terry. "The Emerging Transition Design Approach." *Cuadernos Del Centro de Estudios En Diseño y Comunicación. Ensayos*, no. 73 (2019): 147–79.
[25] Irwin. "The Emerging Transition Design Approach." (2019): 147–79. (p. 158)

envisioning and prototyping possible or even preferable futures" and can lead to "positive shifts in the mindsets, behaviors, and practices that have contributed to wicked problems."[26] Transition Design proposes that it's not enough to merely recognize the necessity of a more sustainable future; we must also craft narratives—visions—that inspire action towards these futures.[27] But these visions should not echo the traditional environmental rhetoric of sacrifice; rather, they should illustrate a future of abundance and prosperity within ecological bounds.[28]

For Transition Design, the process of *visioning* becomes central. The narrative of Dunne and Raby (2013) provides valuable insight here, arguing that visioning is more than just a creative exercise; it is a tool to open the door to debates on alternative futures, a way to embrace how things could be. Irwin draws upon a pantheon of design approaches that foster future envisioning, for example, scenario development, back-casting, and speculative design. These act as counterweights to the inertia of prevailing unsustainable socioeconomic and political systems, enabling ways to 'leap frog' beyond these confines.[29] Transition Design does not offer an unalterable blueprint of the future; instead, it keeps the visions adaptable, rooted in an iterative process that tolerates errors and reshapes itself in response to the always ongoingness of new information. The visioning process becomes a circular dialogue between the present and the future, where even modest designs in the present are informed by radical, continually reworked visions of the future.

Transition Design builds upon speculative approaches by taking the hypothetical futures proposed by speculative design and using them as potential endpoints, or 'North Stars', for transition scenarios. Where speculative design provides possible visions of the future, Transition Design maps out the journey to get there. It does this by designing interventions in the present that can start society on a path toward more desirable futures. It utilizes an understanding of complex systems, sustainability sciences, futures studies, and social innovation to map out possible routes towards these futures. Furthermore, Transition Design emphasizes the importance of designing for the steps or stages that occur between our present and the speculative future, recognizing that these transitions themselves need to be designed in a way that is inclusive, participatory, and responsive to changing conditions over time.

[26] Irwin. "The Emerging Transition Design Approach." (2019): 147–79. (p. 161)
[27] Irwin, Terry. 2015. "Transition Design: A Proposal for a New Area of Design Practice, Study, and Research." *Design and Culture* 7 (2): 229–46.
[28] Irwin, Terry. 2015.
[29] Irwin, Terry. 2015. (p.233)

Collaboration + Design

> "There is a conversation in 'the room' that only these people at this moment can have. Find it." — adrienne marie brown

The history of collaboration and co-design in Human-Computer Interaction (HCI) dates back to the Scandinavian tradition of participatory design, which emerged in the 1970s and 1980s and acknowledges that those who will be affected by a future technology should have an active say in its creation.[30] This process aims to balance power distances between technology creators and users, addressing the unique life worlds, values, needs, and desires of the people affected by the technology. The principles of participatory design laid the foundation for the development of co-design practices in HCI, which expanded the scope to include stakeholders beyond end-users, such as designers, developers, researchers, and domain experts. This collaborative approach to design sought to create more inclusive, accessible, and contextually appropriate technological solutions by leveraging the diverse perspectives, experiences, and expertise of all participants.[31]

In a paper titled "Participation in Design Things," Pelle Ehn explores the concept of "Design Things" and its implications for participatory design. Ehn draws inspiration from the term "thing" in its historical context, where it referred to a gathering or assembly of people for the purpose of discussing and resolving matters of common concern.[32] Design Things, in this sense, can be understood as spaces and processes where various stakeholders come together to participate in collaborative design processes, addressing complex issues and challenges. Ehn argues that these Design Things are not just about designing artifacts or systems but are also *concerned with the politics and power dynamics involved in decision-making and negotiation among the participants*. By emphasizing the importance of participation and collaboration in design processes, Ehn's work contributes to the broader discussion of participatory design and its role in addressing societal and environmental challenges.

Participatory Design (PD) has traditionally focused on human-centered concerns, arising from unease about the impact of automation on workers and later broadening to consider the relationship between people and technology. However, as climate and existential crises force us to examine the well-being of not just humans but all living beings, the concept of participation is expanding to encompass more-than-human perspectives. In her chapter, "Towards a More-than-Human Participatory Research," Michelle Bastian extends participatory research methods to include non-human entities such as animals, plants, and

[30] Robertson, Toni, and Jesper Simonsen. "Participatory Design: An Introduction." In *Routledge International Handbook of Participatory Design*, 21–38. Routledge, 2012.
[31] Robertson and Simonsen. "Participatory Design: An Introduction."
[32] Ehn, Pelle. "Participation in Design Things." In *Participatory Design Conference (PDC)*, Bloomington, Indiana, USA (2008), 92–101. ACM Digital Library, 2008.

even non-living things, challenges traditional anthropocentric approaches, and encourages researchers to consider broader ecological, social, and ethical dimensions in their work.[33]

In their 2020 paper, "Expanding Participation to Design with More-Than-Human Concerns," Yoko Akama and collaborators explore the idea of *always-participating-with-many*, drawing on feminist STS, posthumanism, Shinto, and Indigenous cosmology to reconsider the traditional human-centric view of participation. By examining voice, representation, organizing structure, and decision-making through a more-than-human lens, the authors propose a radically inclusive vision of PD theory and practice that could lead to more sustainable and just worlds.[34] They discuss the politics of multiple ontologies and offer new thinking for co-ontology and explore what an 'ontological braiding' might mean. They suggest "to move between ontologies and propose that readers attempt to hold two (or more) ontologies simultaneously in mind, as a means of fellow-travelling in our subversion of dominant design paradigms."[35]

When considering wicked problems, issues of scale, and co-design, I look to the paper "On Scale, Dialectics, and Affect: Pathways for Proliferating Participatory Design" by Christopher Frauenberger, Marcus Foth, and Geraldine Fitzpatrick. The paper discusses the challenges and opportunities for scaling up participatory design practices, focusing on three key aspects: scale, dialectics, and affect. The authors examine the ways in which participatory design can maintain its values and principles when applied to larger-scale projects or when tackling complex, systemic issues. They argue that the participatory design community should consider the dialectical nature of designing and the role of affect in the design process, which can help create more meaningful connections and engagements with stakeholders.[36]

These selected works in participatory design and co-design have contributed to the ongoing formation of HCI and the broader design community. By rethinking traditional anthropocentric perspectives, embracing more-than-human concerns, and considering the complexities of scale, dialectics, and affect, these insights lay the groundwork for the development of new methods for co-design.

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[33] Bastian, Michelle. "Towards a More-than-Human Participatory Research." In *Participatory Research in More-than-Human Worlds*, 33–51. Routledge, 2016.
[34] Akama, Yoko, Ann Light, and Takahito Kamihira. "Expanding Participation to Design with More-than-Human Concerns." In *Proceedings of the 16th Participatory Design Conference 2020-Participation (s) Otherwise*-Volume 1, 1–11, 2020.
[35] Akama, Yoko, et al. "Expanding Participation to Design with More-than-Human Concerns." (p. 4).
[36] Frauenberger, Christopher, Marcus Foth, and Geraldine Fitzpatrick. "On Scale, Dialectics, and Affect: Pathways for Proliferating Participatory Design." In *Proceedings of the 15th Participatory Design Conference*: Full Papers-Volume 1, 1–13, 2018.

Entanglement + Design

Across this dissertation, *entanglement* is approached as a concept with multiple, domain-specific meanings rather than a settled or unified construct. I began with Frauenberger's "Entanglement HCI: The Next Wave,"[37] which frames entanglement as an ethical and relational condition within human–computer interaction, and this served as an initial anchor for thinking about complexity and interdependence in design. From there, I traced how entanglement appears across human-centered design, anthropology, and the humanities, where it is used to describe situated knowledge, relational agency, ethical dynamics, and more-than-human worlds. Yet even as these literatures enriched my understanding, I found that entanglement was often invoked without clear definition and frequently overlapped with familiar notions such as relations, interdependence, or networks. This lack of conceptual delineation left important questions unresolved and prompted a broader search for other interpretations which ultimately led me to quantum accounts of entanglement that offered more precise and generative ways of thinking about inseparability, indeterminacy, and nonlinear effects.

A more detailed account of how these strands shaped my understanding of entanglement appears in Chapter 7; see Section 7.1.2, *From relational entanglement to quantum entanglement*.

Relational Entanglement

Before turning to quantum interpretations of entanglement, it is necessary to situate how the concept has been taken up in HCI, anthropology, and adjacent humanistic disciplines. In HCI, relational understandings of entanglement are closely tied to longstanding critiques of human-centeredness and calls for more expansive accounts of relationality. Feminist and posthumanist scholarship emphasizes the co-constitution of humans and technologies (Suchman, 2007),[38] the mutual shaping of systems and their publics (DiSalvo, 2009[39]), and the ethical and political stakes of more-than-human design (Bardzell, 2010;[40] Haraway, 2016).[41] Within these traditions, entanglement signals the impossibility of isolating designers, users, artifacts, and environments from the larger assemblages in which they act and highlight the multiple temporalities, histories, and power formations that condition what a design can do and who it can be for.

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[37] Frauenberger, C. (2019). Entanglement HCI The Next Wave? *ACM Transactions on Computer-Human Interaction* (TOCHI), 27(1), 1–27.
[38] Suchman, Lucille Alice. *Human-machine reconfigurations: Plans and situated actions*. Cambridge university press, 2007.
[39] DiSalvo, Carl. "Design and the Construction of Publics." *Design issues* 25, no. 1 (2009): 48-63.
[40] Bardzell, Shaowen. "Feminist HCI: taking stock and outlining an agenda for design." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 1301-1310. 2010.
[41] Haraway, Donna J. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press, 2020.

There have been notable contributions in design and technology fields that mobilize the concept of entanglement, such as Human-Computer Interaction (HCI), STS, and CSCW. HCI is a relatively young field and is known for pulling in theoretical and methodological concepts from other fields. Entanglement has been increasingly applied in these fields to emphasize the complex, interconnected relationships among humans, technology, and the environment. In HCI and design, entanglement is used to describe how the actions, experiences, and meanings of humans and technologies are inseparable and mutually influential.

In their paper, "Entanglement HCI the next wave?" Christopher Frauenberger[42] argues that design frameworks such as Actor-Network Theory (ANT)[43] and Object-Oriented Ontology (OOO), are closely related to entanglement, and share a common focus on the interconnectedness and relationality of elements. However, what separates entanglement from some of the frameworks presented is its emphasis on the entanglement of matter and discourse, and the production of meaning and knowledge through intra-action.[44] With intra-action, co-constitution leads to a position of relational ontology which is expressed as "socio-material configurations, networks, associations, assemblages, ensembles and so on."[45] This meaningful distinction of co-constitution of matter and meaning becomes more prevalent in the design field at the material turn and more specifically in the material-semiotic approach, which connect closely with interpretations of quantum entanglement, as will be discussed in the section below.

In a material-semiotic approach, entanglement is used to understand the relationships between humans, technologies, and the emergence of meaning within their surrounding contexts (Haraway, 2013).[46] This approach acknowledges that material objects (e.g., technologies) and semiotic processes (e.g., meanings and interpretations) are deeply intertwined, influencing each other and co-constructing our experiences. Influential scholars such as Donna Haraway,[47] Bruno Latour,[48] and Karen Barad[49] contributed to the development of this approach through their works on actor-network theory (Latour, 1987; 1993; 2005), feminist science and technology studies (Haraway, 1991; 2016), and agential realism (Barad, 2007), respectively. In a material-semiotic approach, agency is distributed

[42] Frauenberger, Christopher. "Entanglement HCI the next wave?." *ACM Transactions on Computer-Human Interaction (TOCHI)* 27, no. 1 (2019): 1-27.
[43] Latour's Actor-Network Theory calls notice to materiality and issues of infrastructure. For more, see: Bruno Latour. 1996. On actor-network theory: A few clarifications. Soziale Welt 47, 4 (1996), 369–381. DOI:http://www.jstor.org/stable/40878163
[44] Petersson McIntyre, Magdalena. "Agencing Femininity: Digital Mrs. Consumer in Intra-Action." *Journal of Cultural Economy* 13, no. 1 (2020): 54–72. (p. 59)
[45] Frauenberger. "Entanglement HCI the next wave?." (2019)
[46] Haraway, Donna. *Simians, cyborgs, and women: The reinvention of nature*. Routledge, 2013.
[47] Haraway. *Simians, cyborgs, and women.* 2013.
[48] Latour, Bruno. 2005. *Reassembling the Social: An Introduction to Actor-Network-Theory*.
[49] Barad, Karen. 2007. Meeting the Universe Halfway.

among humans and non-humans alike (Pickering, 1995).[50] Both material objects and semiotic processes are considered to have the capacity to act and influence each other, creating complex networks of relationships and interactions (Law, 2004).[51] This approach highlights the importance of context, acknowledging that meanings and relationships are shaped by the specific cultural, historical, and social circumstances in which they occur.

Interdisciplinary collaboration and participatory design are both aspects of entanglement in HCI which emphasizes the integration of multiple perspectives and diverse stakeholders (Frauenberger, 2019;[52] Bannon, 1991;[53] Harrison, Stengers, & Tatar, 2007).[54] Interdisciplinary collaborations pull perspectives from multiple disciplines together in order to create more comprehensive and nuanced understandings of human-technology interactions (Kuutti & Bannon, 2014;[55] Bjögvinsson, Ehn, & Hillgren, 2012;[56] Suchman, 2007;[57] Star, 2010).[58] While participatory design promotes the inclusion of diverse stakeholders in the design process, recognizing that the perspectives and experiences of users, designers, and other stakeholders are interconnected (Schuler and Namioka, 1993;[59] Ehn, 1988;[60] Simonsen and Robertson, 2012;[61] DiSalvo, 2009;[62] Bødker, 2006).[63]

Ethical considerations and reflective practices have been present in HCI since its early days, but have gained more prominence during the 1990s and 2000s (Bannon, 1991;[64] Bardzell,

[50] Pickering, Andrew. "Concepts and the mangle of practice: Constructing quaternions." *South Atlantic Quarterly* 94, no. 2 (1995): 417-465.
[51] Law, John. *After method: Mess in social science research*. Routledge, 2004.
[52] Frauenberger, Christopher. 2019. "Entanglement HCI: The Next Wave?" *ACM Transactions on Computer-Human Interaction*.
[53] Bannon, Liam J. "From human factors to human actors: The role of psychology and human-computer interaction studies in system design." In *Readings in human–computer interaction*, pp. 205-214. Morgan Kaufmann, 1995.
[54] Harrison, Steve, Deborah Tatar, and Phoebe Sengers. "The three paradigms of HCI." In *Alt. Chi. Session at the SIGCHI Conference on human factors in computing systems San Jose, California, USA*, pp. 1-18. 2007.
[55] Kuutti, Kari, and Liam J. Bannon. "The turn to practice in HCI: towards a research agenda." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 3543-3552. 2014.
[56] Bjögvinsson, Erling, Pelle Ehn, and Per-Anders Hillgren. "Design things and design thinking: Contemporary participatory design challenges." *Design issues* 28, no. 3 (2012): 101-116.
[57] Suchman, Lucille Alice. *Human-machine reconfigurations: Plans and situated actions*. Cambridge university press, 2007.
[58] Leigh Star, Susan. "This is not a boundary object: Reflections on the origin of a concept." *Science, technology, & human values* 35, no. 5 (2010): 601-617.
[59] Schuler, Douglas, and Aki Namioka, eds. *Participatory design: Principles and practices*. CRC press, 1993.
[60] Ehn, Pelle. "Work-oriented design of computer artifacts." PhD diss., Arbetslivscentrum, 1988.
[61] Robertson, Toni, and Jesper Simonsen. "Participatory design: An introduction." In *Routledge international handbook of participatory design*, pp. 1-17. Routledge, 2012.
[62] DiSalvo, Carl. "Design and the Construction of Publics." *Design issues* 25, no. 1 (2009): 48-63.
[63] Bødker, Susanne. "When second wave HCI meets third wave challenges." In *Proceedings of the 4th Nordic conference on Human-computer interaction: changing roles*, pp. 1-8. 2006.
[64]Bannon, Liam J. "From human factors to human actors: The role of psychology and human-computer interaction studies in system design." In *Readings in human–computer interaction*, pp. 205-214. Morgan Kaufmann, 1995.

2010;[65] Star & Bowker, 1999;[66] Friedman & Nissenbaum, 1996).[67] The increasing influence of disciplines like sociology, anthropology, and psychology in HCI contributed to a more significant focus on ethics and reflexivity in the field (Suchman, 1987/2007;[68] Dourish, 2001;[69] Kuutti & Bannon. 2014;[70] Harrison, Sengers, & Tatar. 2007).[71] By recognizing the entangled relationships between humans, technologies, and the environment, practitioners can better understand the ethical implications of their work, leading to more responsible, sustainable, and inclusive designs that consider the well-being of all stakeholders, including non-human entities and future generations (Frauenberger, 2019;[72] Haraway, 2016;[73] DiSalvo, 2012).[74] This consideration for entangled relationships encouraged practitioners to reflect on their assumptions, biases, practices, and values fostering a critical awareness of how their work is positioned within and shaped by situ. This reflexivity promotes more responsible and thoughtful design decisions, however, as stated earlier, the mirroring effect between two points may be limited by promoting the illusion of a fixed position, and calls for more development in reflexivity approaches. While notions of entanglement show promise for developing understanding of human-technology interactions, it is crucial to recognize and examine the distinctions of entanglement across different fields, ultimately refining a theoretical and methodological understanding of these complex notions and interactions, and their generative possibilities.

Entanglement has also been used in Anthropology to theorize the inseparability of social, material, and ecological worlds including the complex interactions, interdependencies, and intricate relationships between human and non-human entities, such as animals, plants, minerals, spirits, and objects. Classic and contemporary ethnographic work attends to distributed forms of agency, situated knowledges, and the embeddedness of action in broader systems of meaning (Ingold, 2011;[75] Tsing, 2015[76]). These perspectives foreground relations as the basic units of analysis, showing how networks of kinship, infrastructure,

[65] Bardzell, Shaowen. "Feminist HCI: taking stock and outlining an agenda for design." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 1301-1310. 2010.
[66] Star, Susan Leigh, and Geoffrey Bowker. "Sorting things out." *Classification an its consequences The MIT Press, Cambridge, Massachusetts, London, England* (1999).
[67] Friedman, Batya, and Helen Nissenbaum. "Bias in computer systems." *ACM Transactions on information systems (TOIS)* 14, no. 3 (1996): 330-347.
[68] Suchman, Lucille Alice. *Plans and situated actions: The problem of human-machine communication*. Cambridge university press, 1987.; Suchman, Lucille Alice. *Human-machine reconfigurations: Plans and situated actions*. Cambridge university press, 2007.
[69] Dourish, Paul. *Where the action is*. Cambridge: MIT press, 2001.
[70] Kuutti, Kari, and Liam J. Bannon. "The turn to practice in HCI: towards a research agenda." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 3543-3552. 2014.
[71] Harrison, Steve, Deborah Tatar, and Phoebe Sengers. "The three paradigms of HCI." In *Alt. Chi. Session at the SIGCHI Conference on human factors in computing systems San Jose, California, USA*, pp. 1-18. 2007.
[72] Frauenberger, Christopher. 2019. “Entanglement HCI: The Next Wave?” *ACM Transactions on Computer-Human Interaction*.
[73] Haraway, Donna J. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press, 2020.
[74] DiSalvo, Carl. "Adversarial design as inquiry and practice." (2012): 115-125.
[75] Ingold, Tim. *Being alive: Essays on movement, knowledge and description*. Routledge, 2021.
[76] Tsing, Anna Lowenhaupt. "The mushroom at the end of the world: On the possibility of life in capitalist ruins." In *The Mushroom at the End of the World*. Princeton University Press, 2015.

environment, and political economy constitute each other. For many anthropologists, entanglement is less a conceptual novelty than a methodological stance: an insistence that "following the threads" (Haraway, 2016)[77] of a phenomenon requires attention to contexts, histories, and positionalities that exceed the boundaries of any single actor or event.

Anthropologists also use the concept of entanglement to analyze the ways in which cultural practices and beliefs shape interactions. For example, in some societies, the use of certain natural resources are regulated by complex social norms and taboos that reflect the community's understanding of their relationship with the environment and their responsibilities towards it. In his article "Human-thing entanglement: towards an integrated archaeological perspective," Ian Hodder focuses on humans in Çatalhöyük (7400-6000 BC) in central Turkey and their use of clay in houses, hearths, ovens, figurines, and pottery, and how it affected social divisions, burial practices, and daily sensuous experiences.[78] Mirjana Stevanovic has called this time when clay became a crucial material during the Neolithic period, particularly in the Middle East, the Age of Clay (Stevanović, 1997).[79]

Nicholas Thomas is an anthropologist interested in concerns with the historicity of material objects (as the embodiment of value) as they operate in Oceanic societies in relation to broader issues of colonialism.[80] Thomas critiques older claims that these societies are primordial "gift economies" and any trace of commodity-based economies can be "attributed entirely to variations in the penetration of global capitalism."[81] Instead, Thomas argues that materials, objects, and their meanings are entangled in Oceanic societies, with both gift and commodity forms of exchange operating in different spheres.[82] His work helps us understand that local complexity of meaning around objects is important for understanding contact situations between islanders and colonial agents.

Rosemary Joyce is another anthropologist and archaeologist who is interested in tracing relationships between objects and meaning. She has made significant contributions to our understanding of *traces* and *provenance* in the field of material culture. Her work has focused on the study of objects, particularly ceramics and other artifacts, as a means of illuminating the lives and activities of past societies.[83] By tracing the origin, history, and ownership of objects, Joyce is able to uncover important details about the social networks that existed

[77] Haraway, Donna J. *Staying with the trouble: Making kin in the Chthulucene*. Duke University Press, 2020.
[78] Hodder, Ian. "Human-thing entanglement: towards an integrated archaeological perspective." *Journal of the Royal Anthropological Institute* 17, no. 1 (2011): 154-177.
[79] Stevanović, Mirjana. "The Age of Clay: The Social Dynamics of House Destruction." *Journal of Anthropological Archaeology* 16, no. 4 (1997): 334–95.
[80] Thomas, Nicholas. *Entangled Objects: Exchange, Material Culture, and Colonialism in the Pacific*. Harvard University Press, 2009.
[81]Kaplan, Martha. "Review of Entangled Objects: Exchange, Material Culture, and Colonialism in the Pacific, by Nicholas Thomas." (1993).
[82] Nicholas. *Entangled Objects*
[83] Joyce, Rosemary A. "Social Dimensions of Pre-Classic Burials." *Social Patterns in Pre-Classic Mesoamerica*, 1999, 15–48.

within and between communities, as well as the circulation of materials, ideas, and technologies. For example, in one of her more heavily cited articles, Joyce presents a material tracing of ancient Mesoamerican childhood providing the basis for exploring not only how children were treated, but how they were socialized into particular gender roles.[84] Her work demonstrates that the provenance of artifacts can reveal complex webs of interaction and exchange, providing a more nuanced understanding of past societies and their entangled relationships with the world around them.

Anthropologists have traditionally focused on studying human societies and cultures, with little attention paid to non-human actors such as animals, plants, fungi, microbes, and other elements of the natural world. However, the recognition of the complex and entangled relationships between humans and non-humans has led to a growing interest in the more-than-human worlds. With the emergence of multispecies ethnography, anthropologists are exploring "modest examples of biocultural hope"[85] such as gender-bending bacteria called Wolbachia who can affect reproduction in various host species,[86] and the matsutake mushroom that proliferates in blasted landscapes - a symbol of resilience and hope in the face of environmental and economic devastation.[87] Anthropologists are now exploring how humans are embedded in a web of relationships with other beings "whose lives and deaths are linked to human social worlds."[88] A continuation of tracing entangled relationships among living organisms, including humans, and their physical environment, and how they are situated historical, cultural, and political. These tracings have led to important actions, such as new water justice movements (NWJMs), that acknowledge legal rights to more-than-human entities, "with rivers, who are being recognized as living beings, as ancestral kin, and as multispecies communities."[89]

As climate change, habitat loss, and biodiversity loss become increasingly urgent issues, telling stories of more-than-human entanglements of capitalism, ecology, and culture is critical if we are to understand the ethical and political implications of these relationships

[84] Joyce, Rosemary A. "Girling the Girl and Boying the Boy: The Production of Adulthood in Ancient Mesoamerica." In *The Archaeology of Identities*, 91–100. Routledge, 2007.
[85] Kirksey, S. Eben, and Stefan Helmreich. "The Emergence of Multispecies Ethnography." Cultural Anthropology 25, no. 4 (2010): 545–76.
[86] Kirksey, Eben. "Queer Love, Gender Bending Bacteria, and Life after the Anthropocene." *Theory, Culture & Society 36*, no. 6 (2019): 197–219.
[87] Tsing, Anna Lowenhaupt. *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*. Princeton University Press, 2015.
[88] Kirksey, S. Eben, and Stefan Helmreich. "The Emergence of Multispecies Ethnography." *Cultural Anthropology 25*, no. 4 (2010): 545–76.
[89] Houart, Carlota. "Engaging with Water and Rivers from a Multispecies Justice Perspective." Blue Papers 2, no. 1 (2023): 50-57

and our response-abilities[90] in designing with/for care.[91] This brief overview draws attention to the breadth of anthropological engagements with entanglement. Across the discipline, the ontological and affective turns deepen attention to how modes of being and feeling arise through relational worlds, while multispecies justice scholarship examines the ethical and political stakes of living with others—human and otherwise.[92] At the same time, critical perspectives reveal the limitations and constraints[93] of entanglement as an analytic, drawing attention to patchy Anthropocene conditions,[94] the risks of deferring difference,[95] and the importance of solidarities that remain attentive to power.[96] Together, these strands demonstrate the diversity of anthropological approaches to entanglement and show how the discipline is wide-ranging and continually expanding, offering an expansive space for ongoing exploration into how entangled worlds might be theorized and understood.

Across these literatures, relational entanglement has helped scholars name the complexity of wicked problems such as climate change, environmental injustice, migration, and infrastructural breakdowns, without reducing them to simple explanations. It has also offered designers and researchers a language for acknowledging the partiality of their own perspectives and the ethical obligations that emerge when working with diverse communities and more-than-human environments. At the same time, relational uses of entanglement carry limitations. Because they rely on familiar vocabularies of connection, networks, and interdependence, these accounts often remain anchored in assumptions of separable entities that relate to each other. Even as they describe complex relational dynamics, they frequently treat entanglement as an intensified form of relation rather than as a fundamentally different ontological condition. This can obscure the deeper implications of inseparability, indeterminacy, and nonlinearity– phenomena that become more legible when turning to quantum interpretations of entanglement.

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[90] Response-ability is the capacity to respond. See Haraway and Brown et al. below.; Haraway, Donna. *When Species Meet*. Minneapolis: University of Minnesota Press, 2008.; Brown, Katrina, and Rachel Dilley. "Ways of Knowing for 'Response-Ability'in More-than-Human Encounters: The Role of Anticipatory Knowledges in Outdoor Access with Dogs." *Area 44*, no. 1 (2012): 37–45.

[91] La Bellacasa, Maria Puig de. *Matters of Care: Speculative Ethics in More than Human Worlds*. Vol. 41. U of Minnesota Press, 2017.

[92] Carrithers, M., L. J. Bracken, and S. Emery. "Can a Species Be a Person? A Trope and Its Entanglements in the Anthropocene Era." *Current Anthropology* 52 (October 2011): 661–85.; Schlosberg, David. "Ecological Justice for the Anthropocene." In *Political Animals and Animal Politics*, edited by Marcel Wissenburg and David Schlosberg, 75–89. The Palgrave Macmillan Animal Ethics Series. London: Palgrave Macmillan UK, 2014.; Bubandt, Nils. "Anthropocene Uncanny: Nonsecular Approaches to Environmental Change | Semantic Scholar." In *More Than Human: A Non-Secular Anthropocene - Spirits, Specters, and Other Nonhumans in a Time of Environmental Change*, 2018.

[93] Roberts, Elizabeth FS. "What Gets inside: Violent Entanglements and Toxic Boundaries in Mexico City." *Cultural Anthropology* 32, no. 4 (2017): 592–619.; Giraud, Eva Haifa. *What Comes after Entanglement?* Duke University Press, 2019.

[94]Tsing, Anna Lowenhaupt, Andrew S. Mathews, and Nils Bubandt. "Patchy Anthropocene: Landscape Structure, Multispecies History, and the Retooling of Anthropology: An Introduction to Supplement 20." *Current Anthropology* 60, no. S20 (June 13, 2019): S186–97.

[95] Harris, Kate Lockwood, and Karen Lee Ashcraft. "Doing Power, Deferring Difference: Gendered-Raced Processes and the Case of Karen Barad." *Presented at EGOS 2019*, 2019.

[96] Rabanes, Raphaëlle. "Lateral Solidarity." Somatosphere (blog), March 25, 2019. http://somatosphere.net/2019/lateral-solidarity.html/.

Quantum Entanglement in Quantum Physics

Entanglement as it is used in quantum physics, leads to something different from merely relations, something that challenges our assumptions about existence from a classical physics orientation; namely, a breaking down of classical structures of time and space. What might this nuanced understanding of entanglement offer for speculative practice in design? In what follows, I provide a brief history of quantum entanglement as well as the four concepts from entanglement theory that I will use in relation to design. After each entanglement concept, I describe how the concept might open design to new ways of speculation. The four quantum entanglement concepts I draw on in this dissertation are: Superposition, Observer Effect, Interconnectedness, and Nonlocality & Nonlinearity.

Entanglement theory, also known as quantum entanglement, has its roots in the early 20th century, with the emergence of quantum mechanics as a new theory of physics. The concept of entanglement, which refers to the mysterious and instantaneous connection between particles that are separated by vast distances, was first introduced in a series of papers by Albert Einstein, Boris Podolsky, and Nathan Rosen in 1935.[97] The first paper, “Can Quantum-Mechanical Descriptions of Physical Reality Be Considered Complete?” also commonly referred to as the "EPR paper," raised fundamental questions about the completeness and interpretation of quantum mechanics.[98] Shortly after the EPR publication, physicist Erwin Schrödinger wrote a letter to Einstein using the German word "Verschränkung" which translates into "entanglement."[99] This was the first time the term entanglement was used to describe quantum mechanics. That same year, Schrödinger wrote the paper “Discussion of Probability Relations between Separated Systems,” describing the interaction where two representatives become *entangled*, and a procedure called *the disentanglement*.[100] He describes entanglement as not "one but rather *the* characteristic trait of quantum mechanics, the one that enforces its entire departure from classical lines of thought."[101]

Karen Barad, physicist and philosopher of science, focuses on the role of the observer in quantum mechanics emphasizing the inherent entanglement and inseparability of the observer and the observed, rather than the relational nature of the observer. Barad's

[97] Albert Einstein, Boris Podolsky, and Nathan Rosen, “Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?,” *Physical Review* 47, no. 10 (1935): 777.
[98]Einstein was not happy with the argument made by his co-authors in the original EPR paper because he believed that it violated the principle of locality and implied "spooky action at a distance" between entangled particles. He argued that quantum mechanics could not be a complete theory because it allowed for non-local interactions, which violated his belief in a causally connected universe. Read more about the EPR paradox and early EPR debate here: Arthur Fine. 2004. “The Einstein-Podolsky-Rosen Argument in Quantum Theory”.
[99] Uffink, J. (2020). Schrödinger’s Reaction to the EPR Paper. In: Hemmo, M., Shenker, O. (eds) Quantum, Probability, Logic. Jerusalem Studies in Philosophy and History of Science. Springer, Cham. https://doi.org/10.1007/978-3-030-34316-3_25
[100] Schrödinger, Erwin. "Discussion of probability relations between separated systems." In *Mathematical Proceedings of the Cambridge Philosophical Society*, vol. 31, no. 4, pp. 555-563. Cambridge University Press, 1935.: *555*
[101] Schrödinger. "Discussion of probability relations between separated systems.": *555*

framework, known as *agential realism*, sees the observer as a part of the physical system being observed, inextricably linked and entangled with it.[102] Barad defines agential realism as:

> "an epistemological-ontological-ethical framework that provides an understanding of the role of human and nonhuman, material and discursive, and natural and cultural factors in scientific and other social-material practices, [..] a rethinking of fundamental concepts that support such binary thinking, including the notions of matter, discourse, causality, agency, power, identity, embodiment, objectivity, space, and time."
>
> (p. 26)[103]

Barad based the development of agential realism on the philosophical groundwork laid out by Bohr. They expand and revise his ideas through an engagement with a variety of critical social theories, including feminist theory, critical race theory, queer theory, postcolonial theory, (post-)Marxist theory, and poststructuralist theory. This new engagement with critical social theory opens up questions not only about the nature of reality but also about the nature of scientific and other social practices - a gateway to explore new meanings of entanglement in design. Barad defines entanglement in their book, *Meeting the universe halfway*, starting with the following from the Preface:

> "To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence. Existence is not an individual affair. Individuals do not preexist their interactions; rather, individuals emerge through and as part of their entangled intra-relating. Which is not to say that emergence happens once and for all, as an event or as a process that takes place according to some external measure of space and of time, but rather that time and space, like matter and meaning, come into existence, are iteratively reconfigured through each intra-action, thereby making it impossible to differentiate in any absolute sense between creation and renewal, beginning and returning, continuity and discontinuity, here and there, past and future."
>
> (p. 33)[104]

Quantum Entanglement Concepts

By exploring entanglement through quantum mechanics, I found four concepts that provided conceptual precision and definitional clarity that earlier relational accounts left

[102]Barad, Karen. Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning. duke university Press, 2007.
[103] Barad, Meeting the universe halfway.: 26.
[104] Barad, Meeting the universe halfway.: 33.

unresolved. These four concepts offered more specific and generative ways to think with entanglement in design: *superposition*, *observer effect*, *interconnectedness,* and *nonlocality* and *nonlinearity*.

Superposition

Superposition in entanglement theory refers to the phenomenon in which quantum particles exist in multiple possible states at once, only collapsing into one state when measured. This is the premise behind Schrödinger's (1935)[105] famous thought experiment in which a cat is placed in a sealed box containing a poison that may or may not be released. Until an observer opens the box, the cat is not simply alive or dead, but exists in a superposed state of both. The experiment is not meant to be taken literally, but to illustrate how, at the quantum level, possibilities coexist simultaneously until an observation collapses them into one outcome.

What matters for design is not the physics itself, but what superposition helps us notice about possibility. In quantum theory, multiple states can be "true" at the same time before any single one is selected. This challenges classical assumptions that systems move neatly from one discrete state to another. Superposition instead frames reality as holding plural potentialities—coexisting, overlapping, and unresolved.

In a design context, superposition offers a way to think about early stages of creative and speculative work, when multiple futures, interpretations, and directions are all still in play. It names the generative moment before a concept collapses into a single form, before a design brief is narrowed, before an idea becomes fixed, before the scaffolding of a solution forecloses alternative visions. Holding a superposition means deliberately resisting premature closure, maintaining tensions among competing possibilities, and acknowledging that many futures can be simultaneously viable before choices narrow them.

Observer Effect

Observer effect in entanglement theory refers to the phenomenon where the superposition of entangled particles collapses into a single state through the act of measurement. In the Schrödinger cat experiment mentioned above, the state of the cat collapses when the observer opens the box to determine whether that cat is alive or dead. Prior to this observation the cat exists in both states simultaneously in superposition. As a design

[105] Schrödinger, Erwin. 1935. "Die gegenwärtige Situation in der Quantenmechanik." *Naturwissenschaften* 23 (48): 807–812. English translation: Schrödinger, Erwin. 1935. "The Present Situation in Quantum Mechanics." *Naturwissenschaften* 23: 807–812. (English translation in *Quantum Theory and Measurement*, edited by J. A. Wheeler and W. H. Zurek, Princeton University Press, 1983.)

metaphor, the observer effect can represent the collapsing of potentiality through action. This has radical potential to mean we are shaping the world by what we notice. This could include the framings we perpetuate and our bounded rationality. Barad's framework, known as agential realism, sees the observer as a part of the physical system being observed, inextricably linked and entangled with it. Barad defines agential realism as: "an epistemological-ontological-ethical framework that provides an understanding of the role of human and nonhuman, material and discursive, and natural and cultural factors in scientific and other social-material practices, [..] a rethinking of fundamental concepts that support such binary thinking, including the notions of matter, discourse, causality, agency, power, identity, embodiment, objectivity, space, and time." (Barad, 1999, p.26)[106]

Interconnectedness

Interconnectedness in entanglement theory refers to the interconnected relationships between particles. This shifts attention away from discrete particles and defies Newtonian physics and commonsense assumptions that underlay conventional organizing theory. In a design context, it is an onto-epistemological framing that troubles traditional notions of boundedness and separability. With this framing we can question categorizations or binaries such as human and nonhuman. What does it mean to be human anyway when the reality is, a human consists of a multitude of other organisms living alongside/within the body in a biome. How might the ontological rigidities limit our understanding of potentialities in design?

Nonlocality & Nonlinearity

Nonlocality & Nonlinearity are onto-epistemological framings that trouble traditional notions of space, time, distance, cause and effect, and sequentiality, and determinability. As a design metaphor, nonlocality & nonlinearity become highly open for interpretation, perhaps more so than the other entanglement concepts. Rather than offering a stable or singular definition, these concepts invite designers to reconsider how difference, relation, and responsibility are imagined beyond linear or separable models of the world. This orientation draws directly from quantum-informed critiques of modern sociality, such as those articulated by Denise Ferreira da Silva:

> "Towards re-imagining sociality, the principle of nonlocality supports a kind of thinking that does not reproduce the methodological and ontological grounds of the modern subject, namely linear temporality and spatial separation. Because it violates these framings of time and space, nonlocality allows us to imagine sociality, in such a way that attending to difference does not presuppose separability, determinacy, and sequentiality, the three ontological pillars that sustain modern

[106] Karen Barad, "Meeting the Universe Halfway: Realism and Social Constructivism without Contradiction," in *Feminism, Science, and the Philosophy of Science* (Springer, 1996). p.26.

> thought. In the nonlocal universe, neither dislocation (movement in space) nor relation (connection between spatially separate things) describes what happens because entangled particles (that is, every existing particle) exist with each other, without space-time."
>
> "ON DIFFERENCE WITHOUT SEPARABILITY"
> Denise Ferreira da Silva (p. 64)[107]

Concepts from entanglement theory offer profound lenses through which speculative practices can be expanded and reoriented. These principles invite designers to move beyond bounded rationality by attending to multiplicity, indeterminacy, and cross-scale effects that conventional design methods often overlook. They challenge us to reconsider locality, linearity, and separability as assumptions that limit how we imagine futures and understand sociotechnical systems. At the same time, the abstract nature of entanglement theory poses difficulties for translating these ideas into design practice.

Through this dissertation, I explore how entanglement theory can function as a structuring logic for speculative engagement. By designing workshop activities, materials, and collaborative framings around the four entanglement concepts, I create conditions where participants can actively experiment with these ideas through entangled speculation. Using a modified Research through Design (RtD) approach, I develop concrete methodological pathways for bringing entanglement concepts into practice. Together, this work demonstrates how these concepts can become operational tools for design speculation, expanding how we imagine, create, and critique within HCI.

Entanglement concepts as design orientations

These four concepts from entanglement theory invoke new design orientations: *Superposition* invites designers to hold multiple potentialities in tension, acknowledging that possibilities in design emerge as overlapping, coexisting states until acted upon. The *observer effect* foregrounds the ethical and epistemological implications of design actions, emphasizing that what we notice and measure in design shapes the outcomes and collapses potential futures. *Interconnectedness* challenges categorical binaries like human/nonhuman, urging designers to engage with relational and symbiotic assemblages that reflect the entanglements inherent in ecological and sociotechnical systems. Finally, *nonlocality and nonlinearity* disrupt linear narratives of cause and effect, opening space for speculative approaches that account for dynamic, interdependent phenomena across temporal and spatial scales.

[107] Da Silva, Denise Ferreira. "On difference without separability." *Catalogue of the 32a São Paulo Art Biennial,'Incerteza viva'(Living Uncertainty)* (2016): 57-65.

Critiques of Entanglement

The concept of "entanglement" has gained traction in various academic discourses, often celebrated for its emphasis on intricate, interconnected relationships that defy traditional boundaries and binaries. Eva Haifa Giraud's (2019) work, however, explores the ethical considerations and challenges they present, especially in activist contexts.[108] While acknowledging the interconnectedness of human and more-than-human worlds is crucial, Giraud suggests that it is insufficient to address problems arising from human activities, that there is a need to move beyond celebrating relationality and look deeper into the implications and challenges of entanglements. Giraud's book explores the materialities of communication, the uneven burdens of risk, and the ethical obligations associated with intra-actions. She offers an example, "from a relational, more-than-human perspective, it is human exceptionalism that inhibits restrictions on emissions, reductions in consumption, or further regulation of human engagements with animals within the agricultural-industrial complex. Humanist commitments ensure that issues, conversely, are made to matter politically only to the extent that they impact humans; in line with this perspective, for instance, climate change is seen as warranting action only if it affects people and perhaps even then only certain types of people (with economic benefit often triumphing over environmental concerns)."[109] Focusing largely on the intricacies of food activism and the strategies employed by activists to engage with the public, she emphasizes the importance of adapting and developing new tactics to maximize opportunities for participation touching upon the challenges of balancing values of openness with the need for concrete action. Giraud argues for the importance of highlighting and addressing exclusions. A sole focus on relationality and coming together can obscure these exclusions, making it challenging to address them effectively.[110] Furthermore, the book critiques narrow constructions of care and expertise in the context of animal activism and challenges the representations of animal suffering in media. Giraud emphasizes the importance of recognizing the broader relations that constitute lived realities and the potential pitfalls of overly simplistic or romanticized notions of entanglement that might overlook the coercive or exploitative aspects of certain entanglements, thereby inadvertently perpetuating harmful practices or narratives. By challenging these narrow interpretations, Giraud advocates for a more critical and reflective approach to entanglement, one that recognizes its complexities and engages with its ethical implications. Others have made similar critiques of entanglement.

In "This Will Not Be Generative," Dixa Ramírez-D'Oleo (2023) critically examines the semiotics of ecological writings, particularly focusing on the works of Donna Haraway.[111]

[108] Giraud, Eva Haifa. *What Comes after Entanglement?* Duke University Press, 2019.
[109] Giraud. pp.9.
[110] Giraud. pp.8.
[111] Ramírez-D'Oleo, Dixa. 2023. *This Will Not Be Generative*. Cambridge University Press.

Through the lens of Caribbean literary studies and black critical theory, Ramírez-D'Oleo brings attention to how certain linguistic uses of 'entanglement' can mask extraction from black individuals and blackness. The study contrasts these writings with the horror semiotics found in films, revealing the antagonistic relationship between white survival narratives and the portrayal of blackness. For example, Ramírez-D'Oleo scrutinizes Haraway's use of the term "contact zone," originally coined by literary scholar Mary Louise Pratt. While Pratt's definition emphasizes the spaces of imperial encounters marked by coercion, inequality, and conflict, Haraway's rendition leans more towards relational entanglements, even if asymmetrical.[112] This shift in focus is evident in Haraway's portrayal of the relationship between a scientist and baboons. Haraway describes the baboons' gaze as becoming "entangled" with the scientist's, suggesting a mutual relationship. However, Ramírez-D'Oleo critiques this portrayal, positing that the baboons were coerced into this relationship, having repeatedly communicated their rejection.[113] Ramírez-D'Oleo critique underscores that interpretations can potentially masks the inherent power dynamics and coercive nature of such entanglements, emphasizing the need to recognize the constitutive violence that often precedes and enforces these relational ties.

While these critiques are to be taken seriously and offer needed considerations for interpretations of entanglements, it should be acknowledged that Haraway's work on relational entanglements, and her larger body of work in general, have been foundational in shaping contemporary discussions on human-animal relationships, technology, and feminist theory. Haraway's pioneering ideas challenge traditional binaries and boundaries, pushing for a more interconnected understanding of beings and systems. Her explorations into the intricate web of relationships between species, and her emphasis on the importance of recognizing and valuing these connections, have paved the way for interdisciplinary studies that bridge the gap between the natural sciences, humanities, and social sciences. And have been (and in many ways still are) radical in relation to mainstream academic thought, offering transformative perspectives that continue to inspire scholars, activists, and thinkers across various fields.

It is essential to recognize that critiques, such as those presented by Giraud and Ramírez-D'Oleo, are not mere rejections (even if they are actively scrutinizing or rejecting posited positions) but rather are agential cuts[114] that engage in the larger discourse and build upon prior works. This iterative process of critique and refinement highlights the dynamic nature of academic discourse, where new ideas emerge and take shape through ongoing

[112] Ramírez-D'Oleo. pp.42.
[113] Ramírez-D'Oleo. pp.36.
[114] Barad, Karen. *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. duke university Press, 2007. – Introduces "agential cuts" as moments that constitute phenomena and knowledge through differentiation, not rejection.

engagement with existing conversations, which can be read diffractively to reconfigure new meanings.

Chapter 3: Methods

In this chapter, I define and describe Research through Design (RtD) methods used in this dissertation. I then introduce the three investigations at a high level and describe how the RtD methods apply to each: (1) Post(-)human Hazmat, (2) Speculative F/Actors, (3) and Entangled Justice. This chapter presents the larger RtD arc of this research across investigations, with an in-depth look at each investigation and methods used in chapters 4-6.

What is Research through Design (RtD)?

Research through Design (RtD) is an approach to inquiry that uses the practice of design itself as a method of producing knowledge. Originating with Christopher Frayling's (1993)[115] distinction between *research into*, *for*, and *through* design, RtD foregrounds making and reflection-in-action as ways of engaging with complex, ill-defined, or "wicked" problems (Rittel & Webber, 1973).[116] Rather than beginning with a hypothesis or predefined problem, RtD proceeds through cycles of problem framing and reframing, where designing becomes both the process and object of study (Dalsgaard, 2010;[117] Forlizzi, Zimmerman, & Stolterman, 2009[118]). Forlizzi et al. note an additional critical aspect of RtD, that it "allows researchers to become active constructors of possible futures." (Forlizzi et al., 2009, p. 2894)[119]

In this approach, knowledge emerges through practice, material experimentation, and interaction with contexts of use. As Basballe and Halskov (2012)[120] describe, the dynamics of RtD involve continuous movement between designing, reflecting, and theorizing, where each iteration produces an artifact as well as a refined understanding of the situation and the designer's relation to it. These artifacts are material arguments about what could or should exist, and open potential for new framings, vocabularies, and values. This makes RtD particularly well-suited for addressing wicked and situated problems, where conventional research methods may fail to account for the fluidity of human, social, and material entanglements. It also makes RtD well-suited for developing conceptual

[115] Frayling, Christopher. "Research in art and design (Royal College of Art Research Papers, vol 1, no 1, 1993/4)." (1994).
[116] Rittel, Horst WJ, and Melvin M. Webber. "Dilemmas in a general theory of planning." *Policy sciences* 4, no. 2 (1973): 155-169.
[117] Dalsgaard, Peter. "Research in and through design: an interaction design research approach." In Proceedings of the 22nd conference of the computer-human interaction special interest group of Australia on computer-human interaction, pp. 200-203. 2010.
[118] Forlizzi, Jodi, John Zimmerman, and Erick Stolterman. "From design research to theory: Evidence of a maturing field." Proceedings of IASDR 9 (2009): 2889-2898.
[119] Ibid. Forlizzi et al., 2009, p. 2894
[120] Basballe, Ditte Amund, and Kim Halskov. "Dynamics of research through design." In Proceedings of the Designing Interactive Systems Conference, pp. 58-67. 2012.

frameworks that orient future design, methodological insights that extend design practice, and speculative artifacts that function as propositions or "theories-in-the-making"[121] (Gaver, 2012; Forlizzi et al., 2009). As Forlizzi et al. (2009) note, the outcome of RtD can range from new methods and guiding philosophies to new forms that broaden what design can be.

This makes RtD a particularly fitting approach for this dissertation research, which centers on developing workshops as experimental sites for exploring and speculating on wicked problems through quantum entanglement concepts. The flexibility of RtD allows me to pivot and adapt each workshop through which I can evaluate, reframe, and expand ideas about how design might engage with entangled conditions.

Research through Design (RtD) Approach

The following section describes the approach I take across the three investigations.

The Lab, Field, and Showroom. Koskinen et al.'s (2011) framework of Lab, Field, and Showroom provides us with conceptual "sites" of RtD: "the lab decontextualizes, the field contextualizes, and the showroom allows users to experience ideas made tangible."[122] Koskinen et al. describe combining these according to the needs of the research goals. Each of these are present in each investigation and described in the Select stage.

Five steps to carry out RtD research. This research draws on the five steps for how to carry out an RtD research project from John Zimmerman and Jodi Forlizzi's article "Research Through Design in HCI": 1. Select, 2. Design, 3. Evaluate, 4. Reflect and disseminate, and 5. Repeat (Zimmerman and Forlizzi, 2014).[123] Below I describe the steps. Chapters 4-6 are each dedicated to an investigation where the following steps are worked through.

Step 1. Select

"Select involves choosing a research problem worthy of investigation."[124] This includes deciding on the context of speculative inquiry and the materials that will anchor the exploration including readings, frameworks, sensitizing materials, and physical materials provided in each workshop. Selecting defines the ground of the investigation: the site, medium, and lens through which the work unfolds. As the designer of this research, I chose

[121] Gaver, William. "What should we expect from research through design?." In *Proceedings of the SIGCHI conference on human factors in computing systems*, pp. 937-946. 2012.
[122] Zimmerman, Muriel. "Ilpo Koskinen, John Zimmerman, Thomas Binder, Johan Redstrom, and Stephan Wensveen." (2013): 263.
[123] Zimmerman, John, and Jodi Forlizzi. "Research through design in HCI." In *Ways of Knowing in HCI*, pp. 167-189. New York, NY: Springer New York, 2014.
[124] Ibid. p. 184.

the research problem of each investigation to focus on instantiating entangled speculation in the context of wicked problems.

At the beginning of my PhD, I was drawn to three overlapping but distinct areas of study that would later form the foundation for this first investigation: Posthumanism, Design Justice, and Entanglement. Each provided language for grappling with questions about agency, power, and relationality in design, but I noticed that they often remained siloed from one another.

From Laura Forlano's "Posthumanism and Design" (2017), I encountered the idea of "the hybrid figure of the posthuman," which "greatly expands our understanding of the multiple agencies, dependencies, entanglements, and relations that make up our world." This work challenged the human-centered paradigms that dominate design and invited me to imagine design as a multispecies, more-than-human practice.

Sasha Costanza-Chock's "Design Justice: towards an intersectional feminist framework for design theory and practice" (2018) introduced a way of rethinking design processes by centering those most marginalized by them. It grounded the idea of justice not as an abstract ideal but as a practice of accountability that is attentive to power, history, and lived experience.

Finally, Christopher Frauenberger's "Entanglement HCI: The Next Wave?" (2019) articulated how theories such as Actor-Network Theory, post-phenomenology, and agential realism suggest that "humans and things are ontologically inseparable from the start." This helped me see that design is always already entangled in material, social, and technological networks.

Together, these three areas sensitized me to different ways for approaching wicked problems. Yet as I worked through them, I began to feel that none alone could fully capture the entangled nature of such challenges. Posthumanism emphasized ontological interdependence but risked overlooking histories of dehumanization; Design Justice foregrounded power and inequity but tended to focus on human social systems; and Entanglement HCI offered conceptual tools for relationality but rarely addressed justice directly. Each investigation is a space where these frameworks could coexist, clash, and inform one another through speculative practice.

Step 2. Design

According to Zimmerman and Forlizzi, at the beginning of the design step, researchers "should conduct a literature review to understand the state of the art and the questions and

concerns of other researchers working in this space."[125] I conducted this research as a primary aspect of the development of each workshop. The next phase of the design step is to conduct fieldwork by "holding a design workshop, by playing with a new material, or by exploring ideas in the studio … to understand what the state of the world is and how they might offer a new perspective, a new problem framing, which provides a path to a preferred future."[126] This is followed by "creating new product/service ideas and then select and iteratively evolve and refine an idea into a completed form." Each investigation in this dissertation took a workshop format, however the new "product/service ideas," or rather "new design ideas," are the intended outcomes from the workshops, in that I am interested in what new ideas arrived through the workshop, whether or not, and in what ways, the workshops create opportunities for new speculative engagement for the participants.

What Was Designed

In this dissertation, the primary design outcome is not the discrete artifacts produced during workshops, but the workshops themselves as designed socio-material configurations. Each investigation involved the deliberate design of prompts, materials, facilitation strategies, spatial arrangements, and temporal structures that together shaped the conditions for speculative engagement. Artifacts such as zines, dioramas, knowledge maps, and other material outputs functioned as thinking-with materials, serving as supports for conversation, reflection, and sensemaking rather than as endpoints to be evaluated on their own terms. Accordingly, the analytic focus of this work centers on participants' experiences, including how they interpreted these materials, how their reasoning and sense of possibility shifted through collaborative engagement, and how they articulated learning, tension, and growth over time. This methodological choice reflects an RtD commitment to understanding design as an inquiry into relational and epistemic change rather than as the production of standalone objects, while acknowledging that close material analysis represents a complementary but out-of-scope approach for this dissertation.

Step 3. Evaluate

"Through their process of making and critiquing, the team should evaluate and continually challenge their initial framing. In a sense, each new concept they generate will offer a different framing through its embodiment of a solution, and part of the critique is to explicate the proposal that is embedded in the designer and in their solution. Throughout this process, the team should document their design moves, the rationale (Moran & Carroll, 1996) for these moves, and how different hunches did and did not work out. In addition, the team should reflect on how their framing of the situation evolves and work to capture the

[125] Ibid. p. 185.
[126] Ibid. p. 185.

reasons their framing changes."[127] Each investigation is evaluated at different moments during the design process, using the artifacts produced, the outcomes of the workshops, and through post-workshop participant interviews.

Zimmerman and Forlizzi explain that evaluation should be "based on the concerns of the specific RtD practice they selected (Lab, Field, or Showroom) and on concerns specific to their research question."[128] Projects that follow a Lab practice usually produce multiple related artifacts that can be tested and compared under controlled conditions. Field practice tends to deploy a functioning prototype in real contexts to see whether it shapes behaviors or outcomes as intended, and to observe how people adapt and invent new practices around it. Showroom practice often culminates in a public installation or exhibit where outsiders encounter the design, provoking reflection and dialogue about broader social or technological questions.

Step 4. Reflect and disseminate

"Following the evaluations, the team should reflect on what they have learned and then work to disseminate the research. Dissemination can happen in terms of publication in peer-reviewed venues such as conferences or journals. It might also take the form of a video or demonstration. Finally, for some RtD projects, the work may result in a working system that remains in use by people long after the research project has ended, provoking designers to think about the next problematic situation and solution."[129]

After each investigation, I analyze and reflect on what was revealed from the artifacts, participant interactions, and the workshop's mediating role. These reflections feed directly into the next investigation. I share findings through multiple formats: peer-reviewed publications that articulate conceptual advances in entangled speculation; pictorials that convey the experiential and material dimensions of the work; and installations that allow others to engage the artifacts firsthand. Following this dissertation, I plan to continue to circulate the workshop structures and speculative prompts beyond their original settings, inviting others to adapt them and, in turn, generate new questions about how design can intervene in complex, more-than-human futures.

[127] Ibid. p. 185.
[128] Ibid. p. 185.
[129] Ibid. p. 186.

Step 5. Repeat

"The final step in the process is to repeat. Koskinen et al. (2011)[130] note that RtD researchers who produce the best research results do so by repeatedly investigating the same situation. It is through the development of research programs much more than through individual projects that the best results emerge (See Koskinen et al., 2011: Chap. 10: Building Research Programs)."[131]

In my RtD research, I treat repetition as an intentional form of deepening inquiry. Each investigation revisits core questions about speculative design, entanglement, and justice, but in new contexts, with different materials, participants, and modes of engagement. By returning focus to wicked problems through each workshop, *Post(-)human Hazmat*, *Speculative F/Actors*, and *Entangled Justice*, I build a cumulative research program that allows insights, methods, and theories to take shape through comparison and re-articulation, showing how iterative engagement across distinct yet connected investigations strengthens the overall framework contribution of the dissertation.

Investigations

This section presents the three distinct investigations that collectively inform the framework of this dissertation. Each investigation looks at a speculative workshop that builds upon the foundations of speculative and participatory design, incorporating interdisciplinary perspectives to explore justice-oriented and more-than-human design practices. The investigations are: (1) *Post(-)human Hazmat*, a 10-session workshop focused on speculative storytelling for multispecies care in the context of climate crises; (2) *Speculative F/Actors*, a workshop series aimed at fostering entangled approaches to collaborative worldbuilding on the topic of climate futures; and (3) *Entangled Justice*, a workshop series examining entangled complexities of climate migration, marine energy, and the circular economy. Each workshop was intentionally designed to attend to different ways of staying with the trouble. Each workshop (and its development) provide a space for investigation and reflection; each with their own findings, benefits, and limitations. Together, these investigations provide a range of approaches to engaging with wicked problems.

[130] Koskinen, Ilpo, John Zimmerman, Thomas Binder, Johan Redstrom, and Stephan Wensveen. "Design research through practice: From the lab, field, and showroom." *IEEE Transactions on Professional Communication* 56, no. 3 (2013): 262-263.
[131] Zimmerman, John, and Jodi Forlizzi. "Research through design in HCI." In *Ways of Knowing in HCI*, pp. 167-189. New York, NY: Springer New York, 2014.. p. 186.

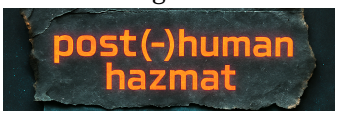
	Investigation 1	*Investigation 2*	*Investigation 3*
			
Participants	11 (UW students)	8 (UW students)	9 (practitioners)
Format	Ten sessions (2-hours each)	Three, 1-hour workshops	Three, 1-hour workshops
Descriptions	Independent making and collaborative critique exploring speculative storytelling, multispecies care, and ontological troubling.	Collaborative worldbuilding that explores entangled relational dynamics from situated to nonlinear, nonlocal realities.	Independent and collaborative engagements using knowledge mapping to explore justice dynamics within highly specific domains.
Output	Zine of stories	Dioramas of climate futures	Knowledge maps

Table 3.1. *Methods and Description for each Investigation.*

Investigation 1. Post(-)human Hazmat: Focus on speculative storytelling, multispecies care, and ontological troubling.

Investigation 2. Speculative F/Actors: Emphasis on collaborative worldbuilding and entangled relational dynamics and nonlinear and nonlocal realities.

Investigation 3. Entangled Justice: Engagement with dimension from Writing the Implosion, and highly specific topics of inquiry.

All research conducted in these investigations were approved by the institutional review board at the University of Washington and given an exempt status. Despite the exempt status, all participants were offered information about the study and consent forms were provided to determine if photographs and materials created during the workshops could be used in the research. Recruitment was conducted differently for each investigation and is described in each subsequent investigation chapters.

Research Team: Facilitation and Documentation

As the sole facilitator across the investigations, I shaped both the structure of the workshops and the conditions under which participants engaged with speculative work. Decisions to emphasize playfulness, openness, and restraint were intentional, reflecting a belief that imaginative capacity and care are more likely to emerge when participants are not pushed toward premature resolution. This facilitation approach was designed to shape how participants navigated uncertainty, related to one another, and remained engaged with complex and entangled problems.

To support facilitation and data collection for the final *Speculative F/Actors* and *Entangled Justice* workshops, I led a Directed Research Group (DRG) in Autumn (September-December) 2023 titled "Workshops for Wicked Problems: Mapping Ethical Relations and Responsibilities in Multidisciplinary Collaborations." The DRG included six HCDE students, three undergraduate (BS) and three graduate (MS), who contributed to workshop setup, facilitation, and documentation of both *Speculative F/Actors* and *Entangled Justice* workshop. See the schedule below, in Figure 3.1.

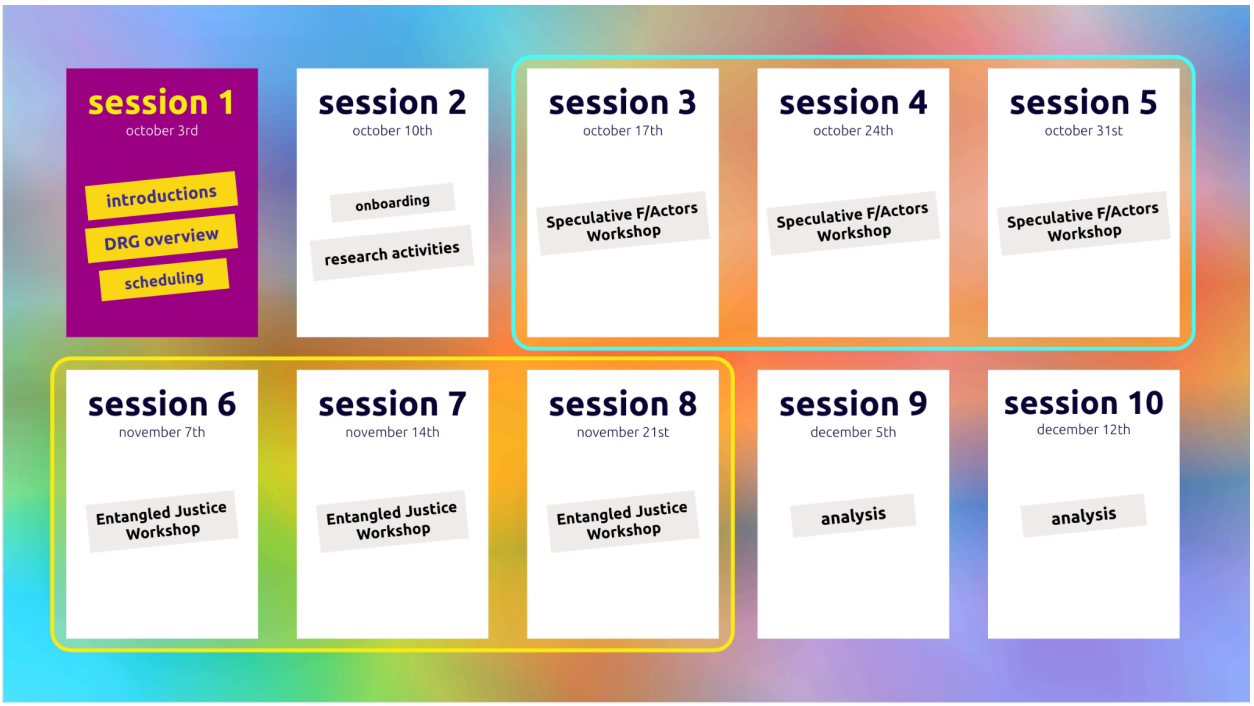


Figure 3.1. DRG Schedule*: "Workshops for Wicked Problems: Mapping Ethical Relations and Responsibilities in Multidisciplinary Collaborations" (HCDE 496/596).*

The first two DRG sessions introduced the goals and activities of the project, allowed researchers to sign up for specific workshops, and provided an overview of the research methods through guided practice. Sessions 3-5 focused on facilitating and documenting the *Speculative F/Actors* while Sessions 6-8 focused on facilitating and documenting the *Entangled Justice* workshop. Sessions 9-10 were dedicated to data processing and preliminary analysis.

Speculative F/Actors

The research team assisted with audio and video recording, note-taking, and organizing workshop materials before and after each session. Figure 3.2 (below) shows the intended layout of the recording setup and workspace arrangement for *Speculative F/Actors*. Figures 3.3 and 3.4 (below) show examples of camera angles from the top and from the side.

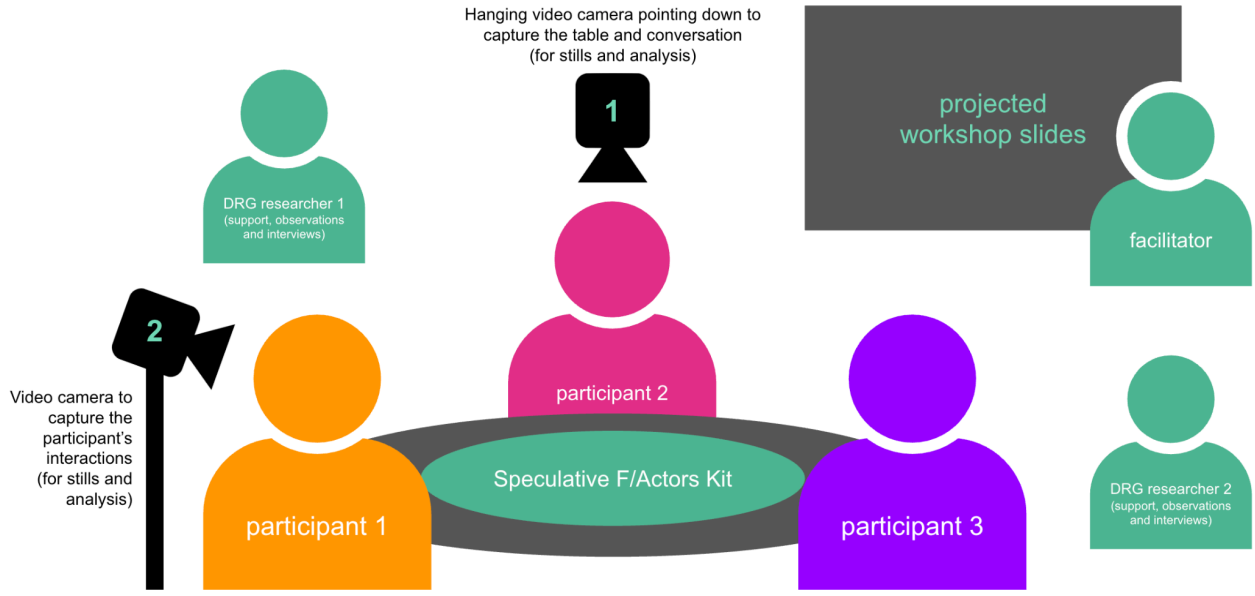


Figure 3.2. *Speculative F/Actors Workshop Layout: Shows the layout of the participants, kit, researchers and facilitator, and technology (projector and two cameras capturing video and audio).*

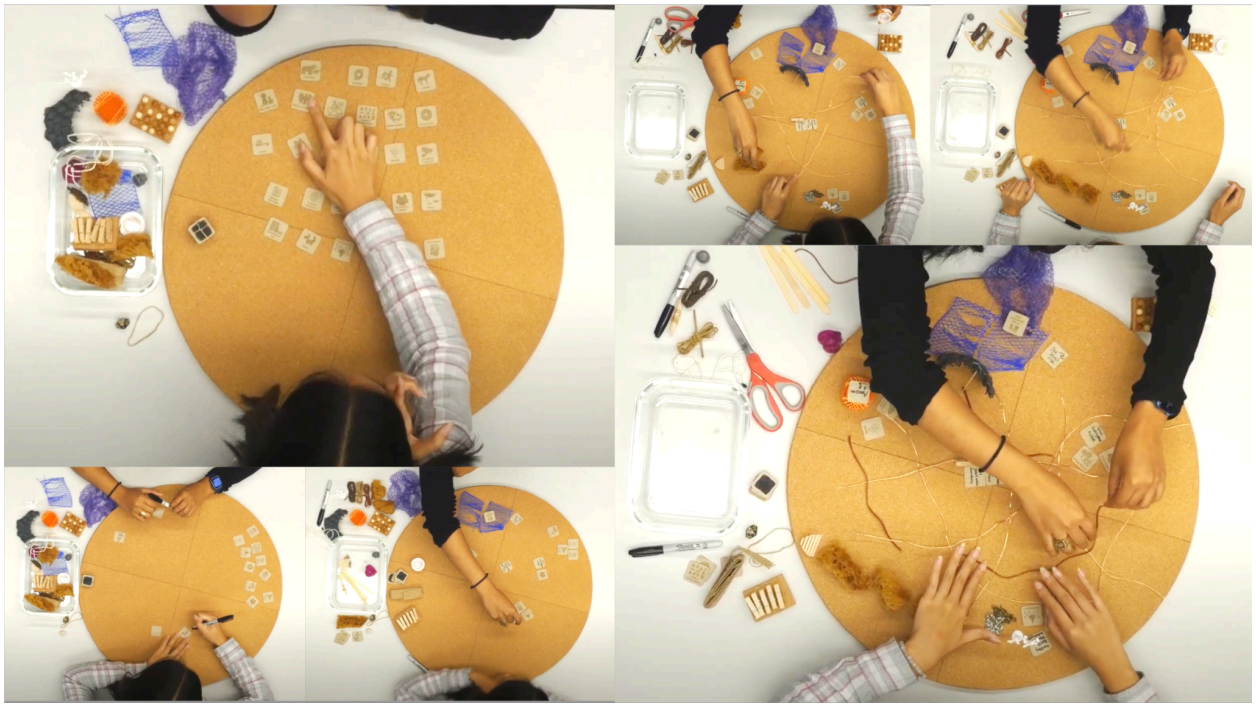


Figure 3.3. *Speculative F/Actors Workshop Layout: Camera angle from the top.*

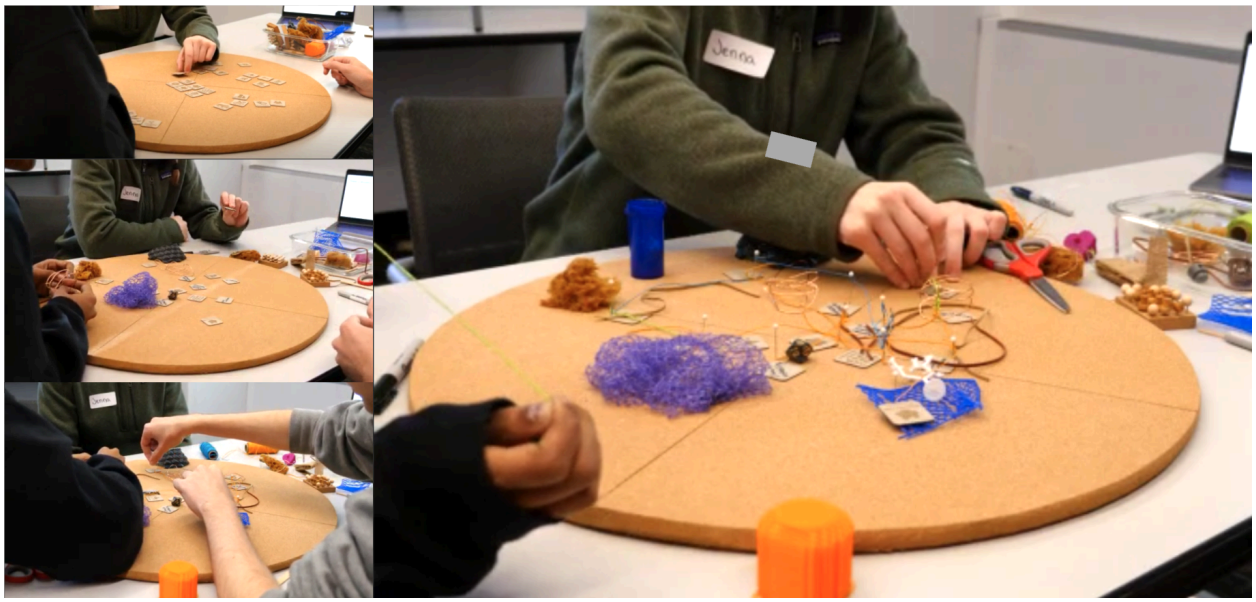


Figure 3.4. *Speculative F/Actors Workshop Layout: Camera angle from the side.*

To ensure high-quality recordings for analysis, we conducted three separate workshops, each with a small group of participants. Workshop 1 included two participants, while Workshops 2 and 3 each included three participants, totaling eight participants across all sessions. This structure allowed for individual post-workshop interviews, with each participant paired with a researcher from the documentation team.

Entangled Justice

The research team assisted with note-taking before and after each session, and data collection with post-workshop interviews. These workshops were conducted over Zoom and audio and video recorded. Participant interviews were conducted either after the workshop, or scheduled for a few days later.

Research Team: Interpretation

Following data collection, a second Directed Research Group (DRG) was established to support the analysis phase for *Speculative F/Actors* and *Entangled Justice* workshops called, "Workshops for Wicked Problems II: Qualitative Coding and Analysis of Workshop Data." The video and audio recordings for both investigations were transcribed, qualitative coded, and analyzed in DRG II. See the schedule for "Workshops for Wicked Problems II" below in Figure 3.5.

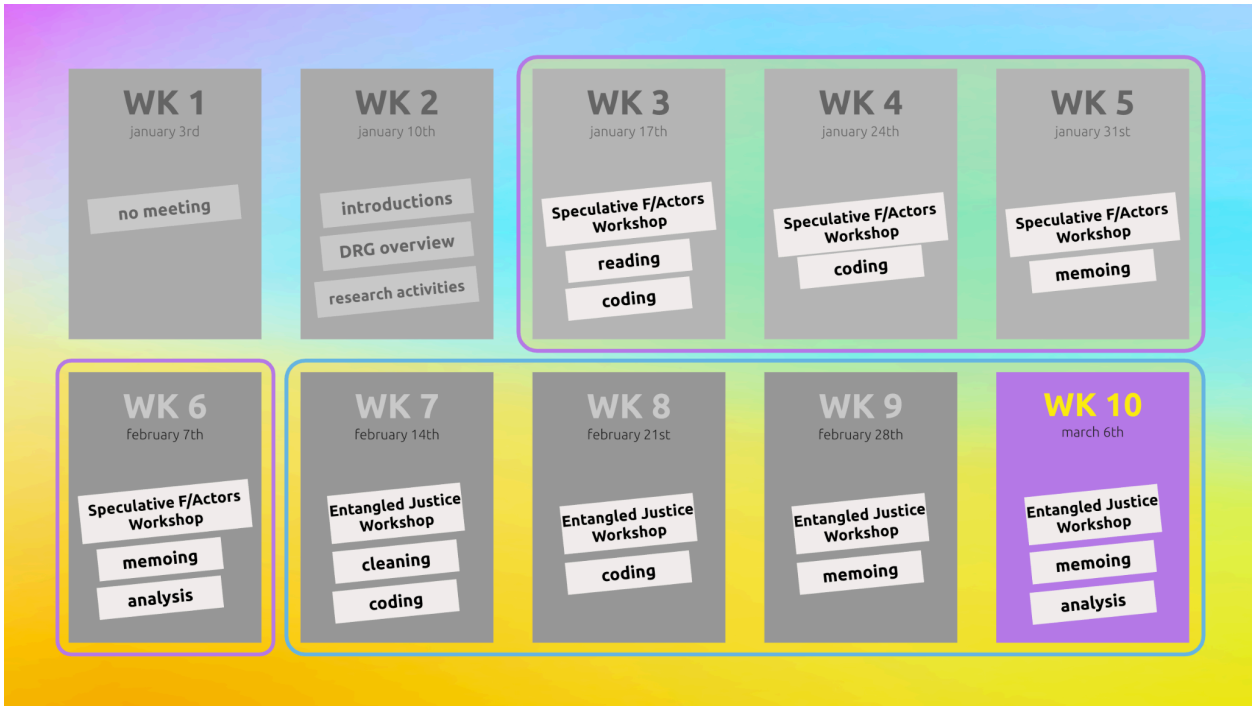


Figure 3.5. *DRG II Schedule: "Workshops for Wicked Problems II: Qualitative Coding and Analysis of Workshop Data" (HCDE 496/596).*

The first two sessions of DRG II introduced the goals of the analysis phase, reviewed qualitative coding methods, and oriented researchers to the datasets from the *Speculative F/Actors* and *Entangled Justice* workshops. Sessions 3-6 focused on *Speculative F/Actors* analysis while sessions 7-10 focused on *Entangled Justice* analysis. For each investigation, the research team worked through transcript review, qualitative coding, and discussions to compare and refine emerging themes.

This analysis work for *Speculative F/Actors* was done on a shared Miro board, see a high level screenshot below in Figure 3.6. This shows how I organized the analysis for the workshop transcript (top right, orange), The interview transcripts (bottom left, purple), and qualitative analysis (right, green).

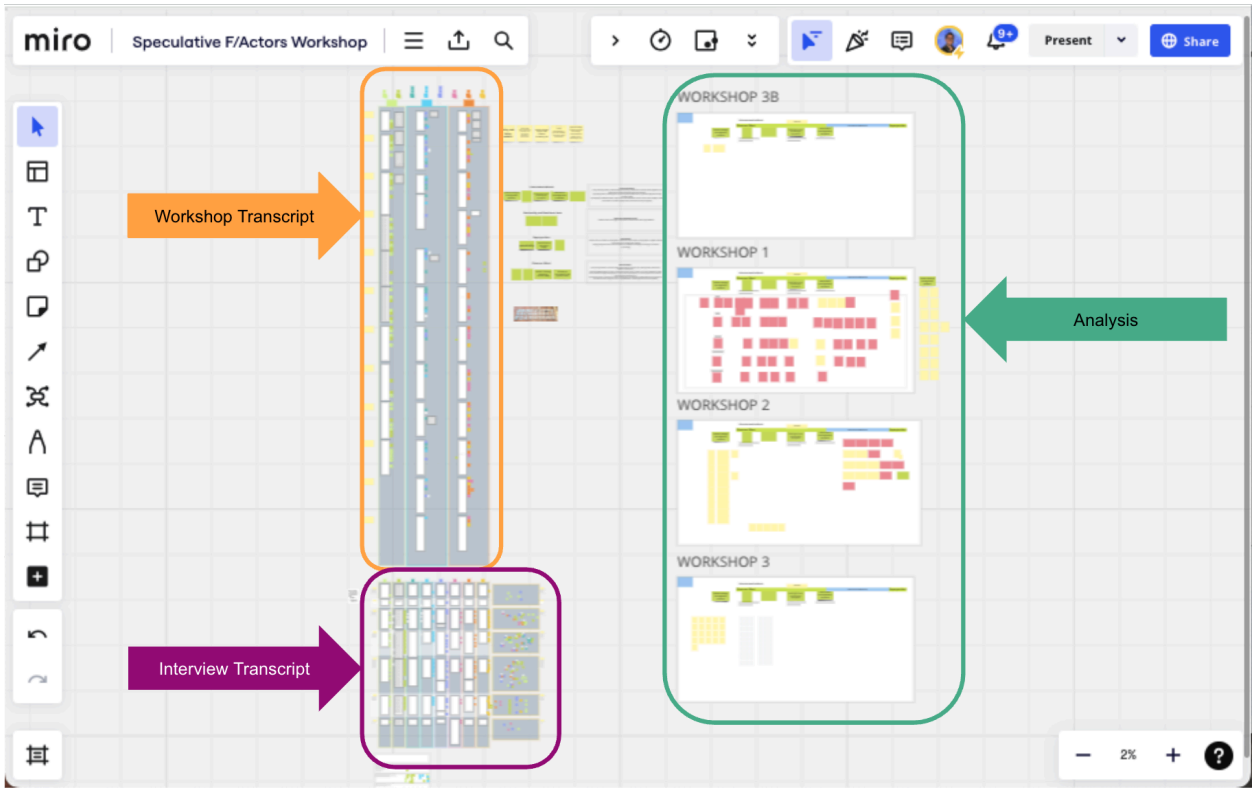


Figure 3.6. High-level *screenshot of the Miro board for Speculative F/Actors workshop and interview transcript analysis.*

Figure 3.7 (below) shows a zoomed in screenshot of the workshop transcript section. Here you can see the transcript is paired with qualitative codes, and memos and pull quotes, identified by the research team. And Figure 3.8 (below) shows a zoomed in screenshot of the interview transcript section. Here you can see the transcripts are paired with the research questions in the first column, qualitative codes, and card sorting that led to the final analysis.

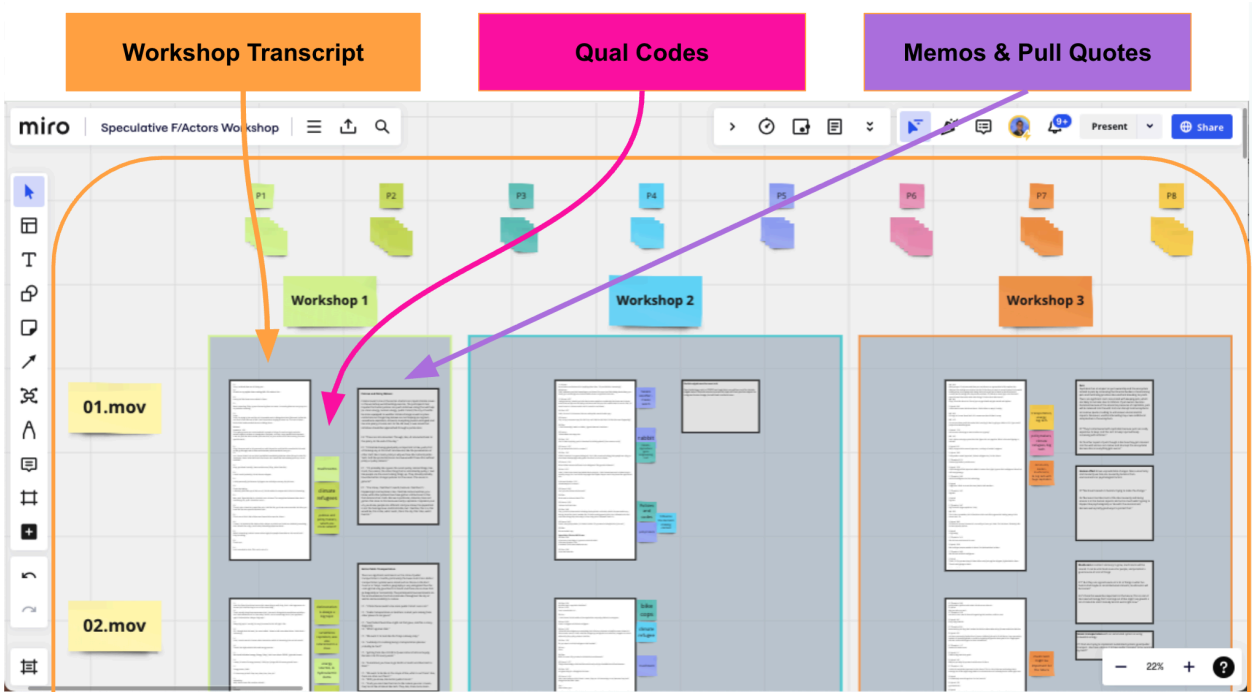


Figure 3.7. *Screenshot of the Miro board for Speculative F/Actors workshop transcript analysis.*

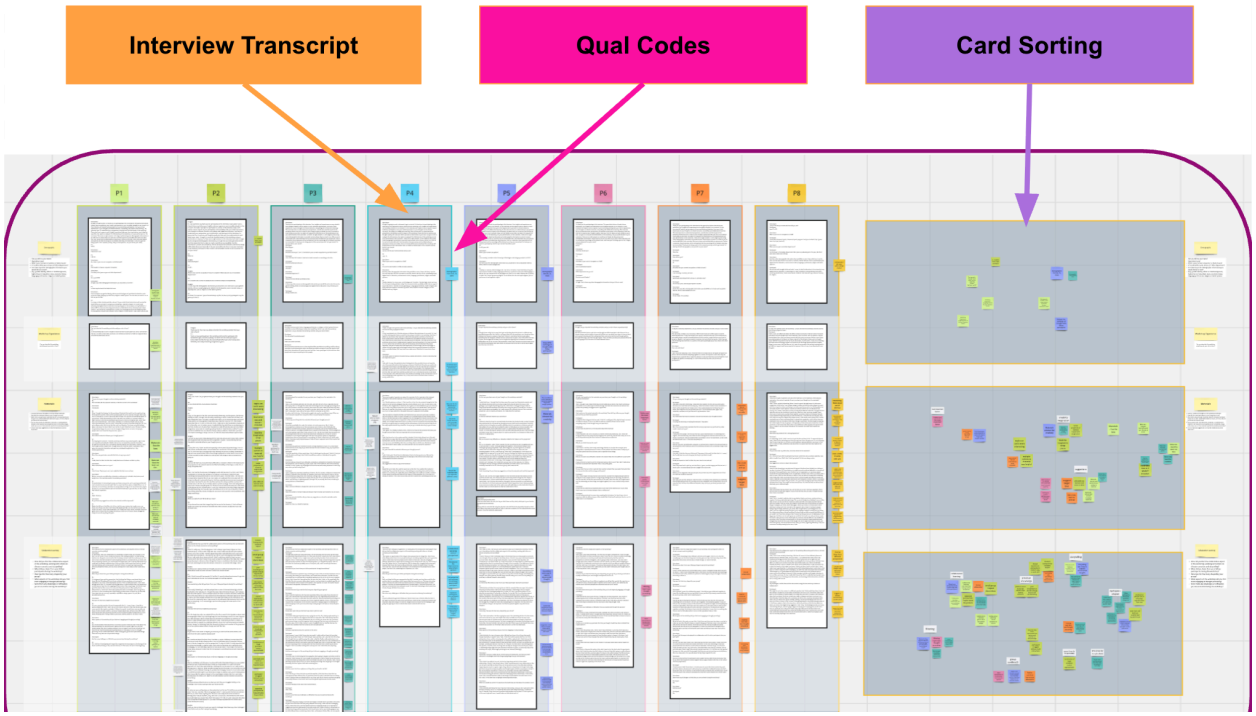


Figure 3.8. *Screenshot of the Miro board for Speculative F/Actors interview transcript analysis.*

The analysis work for *Entangled Justice* was also done on a shared Miro board, see a high level screenshot below in Figure 3.9. This shows how I organized the analysis for the workshop transcript (top right, orange), The interview transcripts (bottom left, purple), and qualitative analysis (right, green).

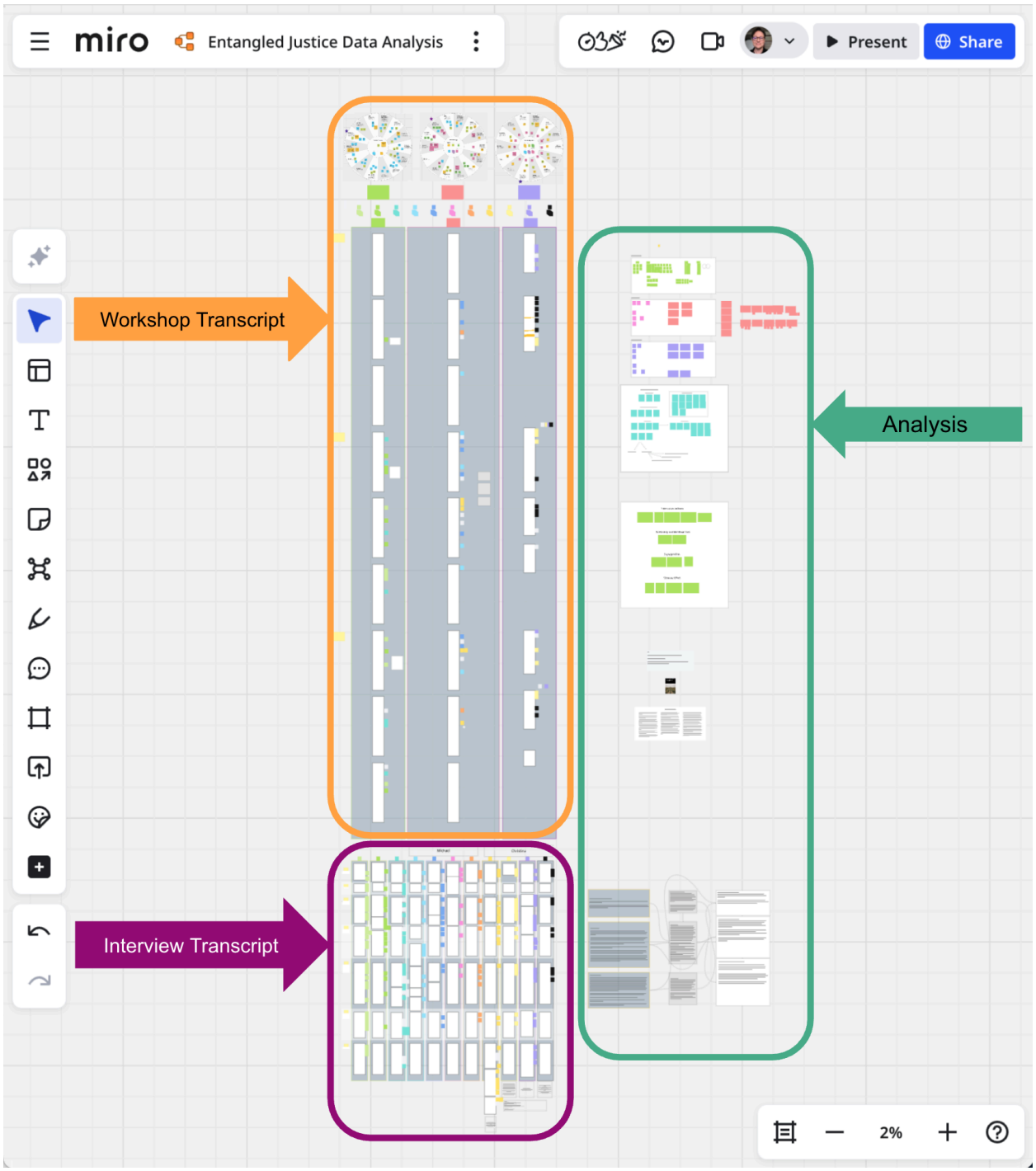


Figure 3.9. High-level *screenshot of the Miro board for Entangled Justice workshop and interview transcript analysis.*

Figure 3.10 (below) shows a zoomed in screenshot of the workshop transcript section. Here you can see the transcript is paired with qualitative codes, and memos and pull quotes, identified by the research team. And Figure 3.11 (below) shows a zoomed in screenshot of the interview transcript section. Here you can see the transcripts are paired with the research questions in the first column, qualitative codes, and memos and insights that led to the final analysis.

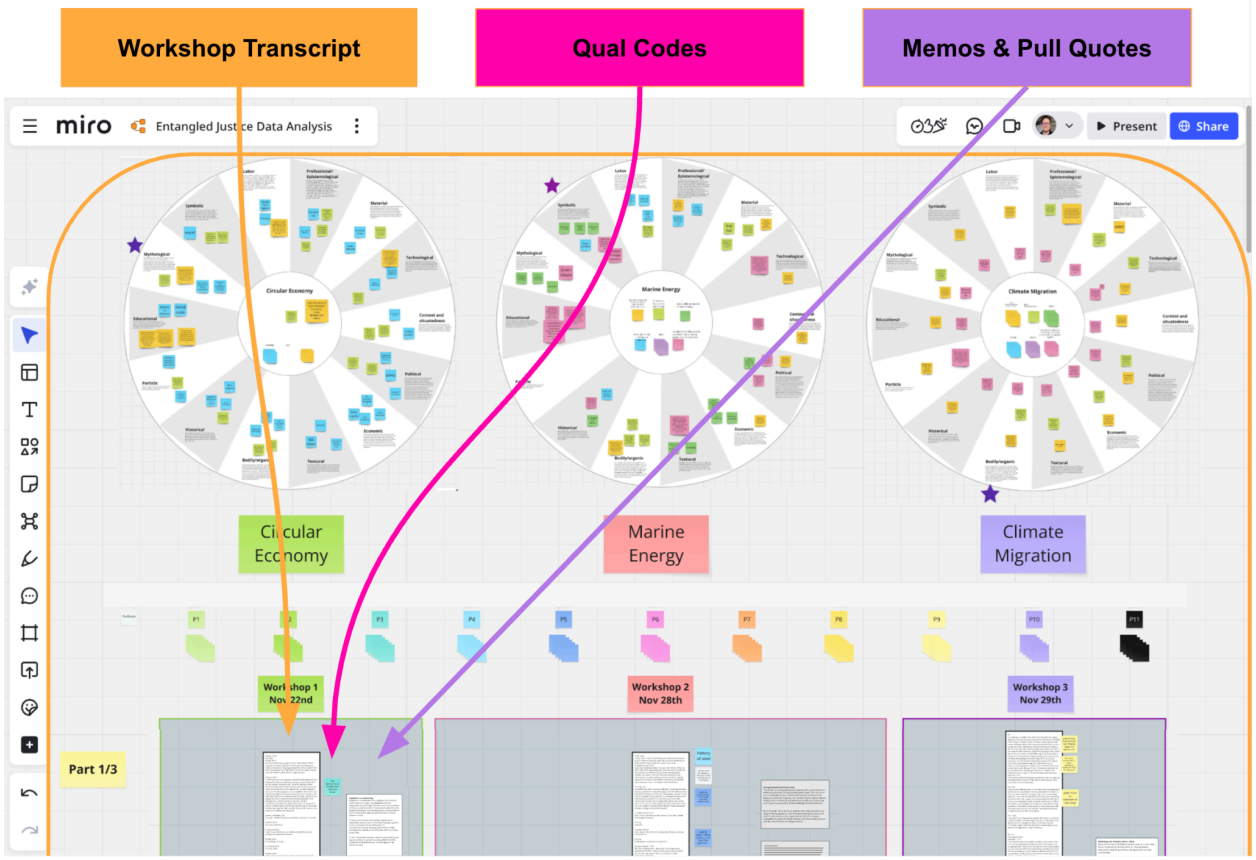


Figure 3.10. *Screenshot of the Miro board for Entangled Justice workshop transcript analysis.*

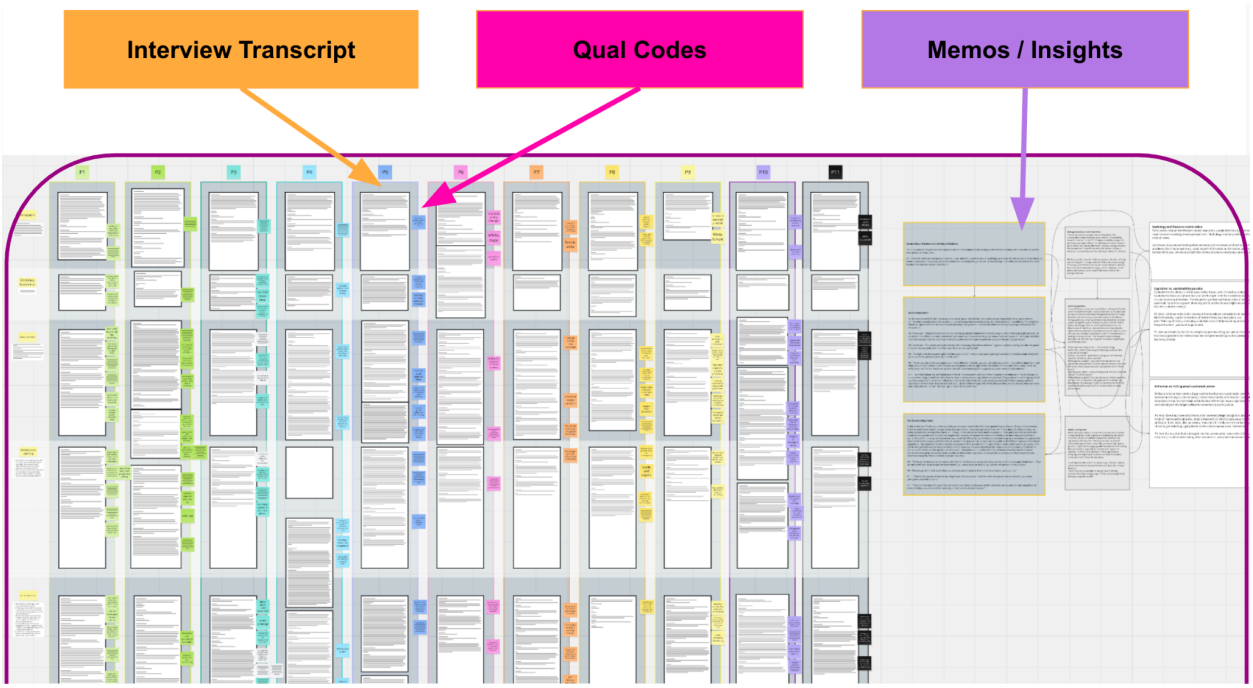


Figure 3.11. *Screenshot of the Miro board for Entangled Justice interview transcript analysis.*

Chapter 4: Investigation 1 - Post(-)human Hazmat

Step 1: Select

At the core of my dissertation lies a question that has followed me throughout my PhD journey: How might we design for wicked problems?

Wicked problems are those that defy simple solutions or bounded scopes such as climate change, loss of biodiversity, and systemic inequality. These challenges are entangled across scales: from the hyper-local to the planetary, from bodily experiences to infrastructural and ecological systems. They are shaped by economic, political, and epistemological structures that design intentionally or more often inadvertently participates in maintaining. Wicked problems are therefore not only technically complex but also morally and relationally complex.

Designing for wicked problems demands rethinking what responsibility and intervention mean when effects are distributed and inseparable. To engage with such conditions, this research turns to entanglement as a theoretical and methodological construct for breaking down categorical assumptions. Drawing from Barad's (2007)[132] agential realism, entanglement illuminates how beings and things do not preexist their relations but rather come into being through intra-actions. This shift complicates the notion of a discrete "designer" acting upon a problem space to identify "solutions" as is found in traditional approaches to design; it instead situates design as an ongoing practice that is already embedded within a web of relations that include materials, technologies, institutions, histories, and ecologies.

[132] Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press, 2007.

This investigation is worth pursuing because it contributes to ongoing efforts to reorient design from human-centered control toward ethical attunement and relational responsibility. It draws on and contributes to movements in design research that foreground justice, care, and more-than-human relations (Costanza-Chock, 2018;[133] Forlano, 2017;[134] Frauenberger, 2019),[135] each offering vital insights into the distributed, ethical, and ontological conditions of design, yet they also reveal tensions when faced with the scale and complexity of wicked problems.

Why was this particular site, theme, and provocation chosen?

This first investigation emerged from the intersection of the three theoretical orientations that shaped my methodological grounding: Posthumanism, Design Justice, and Entanglement HCI, as discussed in Chapter 3. *Post(-)human Hazmat* became the initial site for testing how these frameworks might be brought into speculative practice together.

I needed a methodological structure that could ground that experimentation. Value Sensitive Design (VSD) provided that starting point. VSD is a design methodology that integrates human values systematically throughout the design process, combining conceptual, empirical, and technical investigations to address ethical concerns (Friedman, Kahn, & Borning, 2008).[136] Traditionally, VSD uses value scenarios, or narrative sketches that make potential ethical tensions explicit among human stakeholders, as a way to anticipate the social implications of design decisions. In *Post(-)human Hazmat*, I reimagined this approach to consider how values might operate across more-than-human relations, where agency and vulnerability are distributed among humans, technologies, and other species. By transforming value scenarios into speculative storytelling exercises, participants could surface and reflect on tensions of care, reciprocity, and survival in imagined worlds. This adaptation positioned VSD as a speculative and ethical practice that makes visible how values are entangled when the very notion of "stakeholder" is explored and unpacked.

Post(-)human Hazmat is a site where I could experiment with how these theoretical threads might be mobilized through speculative design practice. The title itself was an ethico-onto-epistem-olgical[137] provocation: "Post(-)human" gestures toward the tensions

[133] Costanza-Chock, Sasha. 2018. Design justice: Towards an intersectional feminist framework for design theory and practice. In Proceedings of the Design Research Society (DRS '18).
[134] Forlano, Laura."Posthumanism and design. "She Ji: The Journal of Design, Economics, and Innovation 3, no. 1 (2017): 16-29.
[135] Frauenberger, C. (2019). Entanglement HCI The Next Wave? ACM Transactions on Computer-Human Interaction (TOCHI), 27(1), 1–27.
[136] Friedman, Batya, Peter H. Kahn Jr, Alan Borning, and Alina Huldtgren. "Value sensitive design and information systems." In *Early engagement and new technologies: Opening up the laboratory*, pp. 55-95. Dordrecht: Springer Netherlands, 2013.
[137] Barad (2007) describes *ethico-onto-epistem-ology* as "an appreciation of the intertwining of ethics, knowing, and being—since each intra-action matters, since the possibilities for what the world may become call out in the pause that precedes each breath before a moment comes into being and the world is remade again, because the

and troubles of what it means to be, or move beyond, the "human" without erasing histories of dehumanization; while "Hazmat" evokes tensions and troubles of entangled ecologies. Drawing inspiration from Donna Haraway's work, the workshop examined the ontological notion of the human, with a particular focus on the concept of the *holobiont*,[138] a term Donna Haraway uses to mean:

> "symbiotic assemblages, at whatever scale of space or time, which are more like knots of diverse intra-active relatings in dynamic complex systems than like the entities of a biology made up of preexisting bounded units (genes, cells, organisms, etc.) in interactions that can be conceived only as competitive or cooperative."[139]
>
> (p. 26)

The workshop became a testing ground for exploring these overlapping sensibilities through collective speculative storytelling. It offered a way to materialize theory to see how students might navigate notions of care, responsibility, and survival when theory was translated into practice.

How does this investigation initiate a cycle of RtD?

I did not know how this workshop would turn out, how it would be received by participants, or what kinds of output it might create. I knew it would be experimental, but taking a risk in designing a workshop for engaging with wicked problems seemed daunting. It might require ongoing iteration or last minute pivots over the course of the 10 sessions. Since wicked problems resist closure and require a multiplicity of approaches, I felt confident that future workshops would need to be reimagined for different contexts, audiences, and purposes. Rather than seeking to "get it right" the first time, I approached this first investigation as the opening to an iterative process, a cycle of inquiry, making, and reflection that would continue across subsequent investigations.

This investigation initiates the first of three iterative RtD cycles described in Chapter 3, each probing different approaches to designing for entangled speculation. It marks the beginning of the larger research arc, a point of departure where theory met practice, and where the groundwork was laid for developing a design framework attuned to the entangled conditions of wicked problems.

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becoming of the world is a deeply ethical matter" (p. 185).; Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press, 2007.

[138] Haraway, Donna. "Symbiogenesis, Sympoiesis, and Art Science Activisms for Staying with the Trouble." *Arts of Living on a Damaged Planet*, 2017, M25–50.

[139] Haraway, "Symbiogenesis, Sympoiesis, and Art Science Activisms for Staying with the Trouble." (p. 26)

Step 2: Design

Designing for wicked problems is not a well-established or formulaic practice in design; it requires inventing processes that can hold uncertainty, multiplicity, and contradiction. For the Post(-)human Hazmat investigation, I began by focusing on the ontological challenges at the heart of posthuman and more-than-human inquiry, questions about what counts as "human," what relationships sustain life, and how design might intervene in those relations without collapsing their complexity. I approached the design of this workshop as an experiment in translating dense theoretical ideas into visual and narrative artifacts that could make these ideas graspable and discussable through creative practice. Rather than constraining participants' imaginations to what was likely, plausible, or even possible, I turned to feminist science fiction as a guiding mode for design.

This framing opened a speculative space for participants to imagine otherwise. This led to a focus on the process of narrative construction, exploring how participants may distinctly interpret the sensitizing materials to craft stories, images, and alternative futures that challenge anthropocentric norms and explore scenarios of multispecies care and collaborative survival.

Early in the design process, I assembled a large pool of potential readings, concepts, and activity ideas drawn from my own research interests in speculative design, feminist technoscience, and posthumanism. I treated this as a curatorial process: selecting and sequencing materials that could progressively build conceptual depth while maintaining creative openness. The selection process unfolded visually and iteratively across a series of whiteboard sketches. Image 1 (below) documents an early mapping of ten potential sessions, with clusters of candidate readings and speculative prompts. It is here where the workshop title formed, "Post(-)human Hazmat: Design fiction for multispecies care and collaborative survival in cataclysmic climates."[140]

[140] An article about the DRG was written for Designing Up magazine. See: https://www.hcde.washington.edu/designing-up/2021/post-human-hazmat

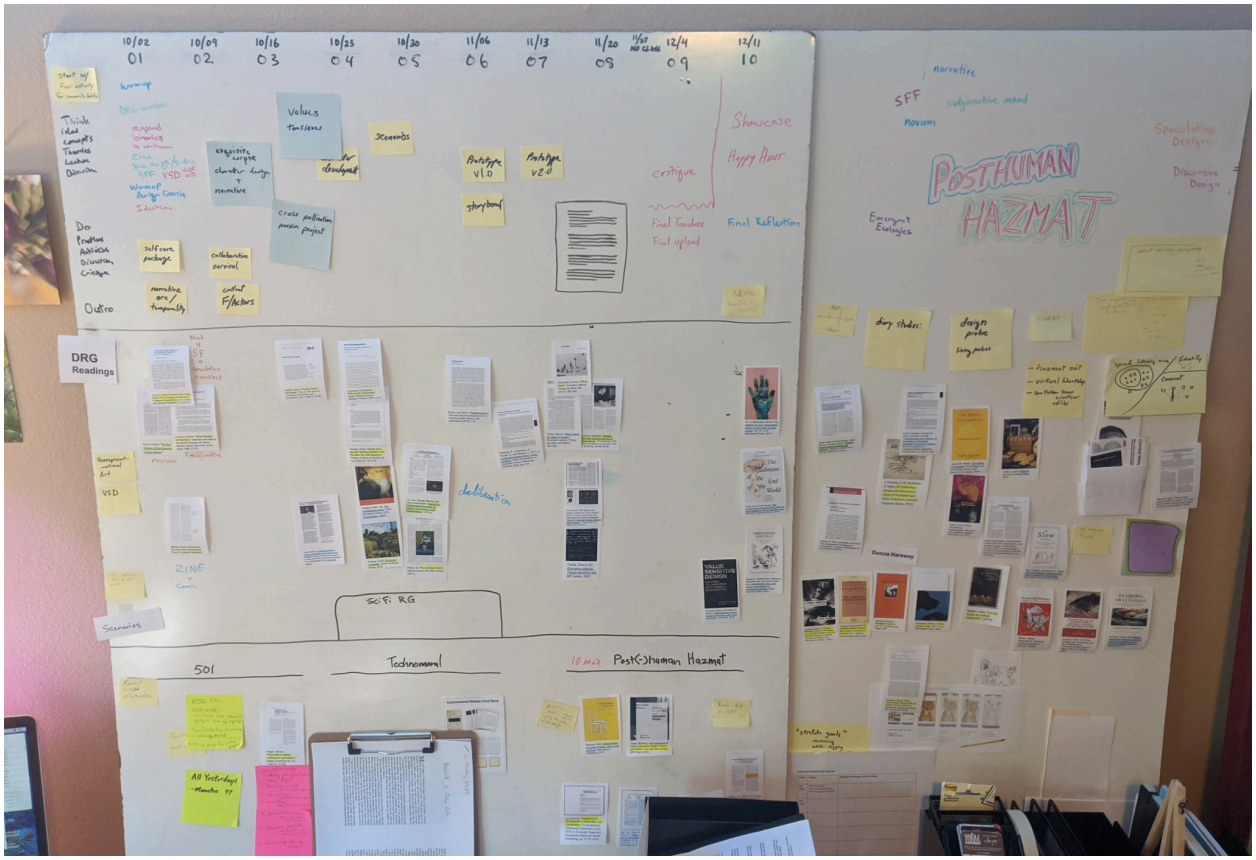

Figure 4.1. *Design process 1: Whiteboard where I designed the 10 sessions including a pool of readings and notes about potential activities*.

Image 2 (below) shows a later iteration in which I refined the sequence, organizing the ten sessions into a cohesive narrative arc, with readings, in-class discussions, and homework assignments arranged to scaffold participants' engagement from theoretical grounding toward artifact creation. This visual structuring process helped me align the workshop's pedagogical rhythm with its speculative intent—ensuring that each session balanced conceptual provocation with opportunities for imaginative experimentation.

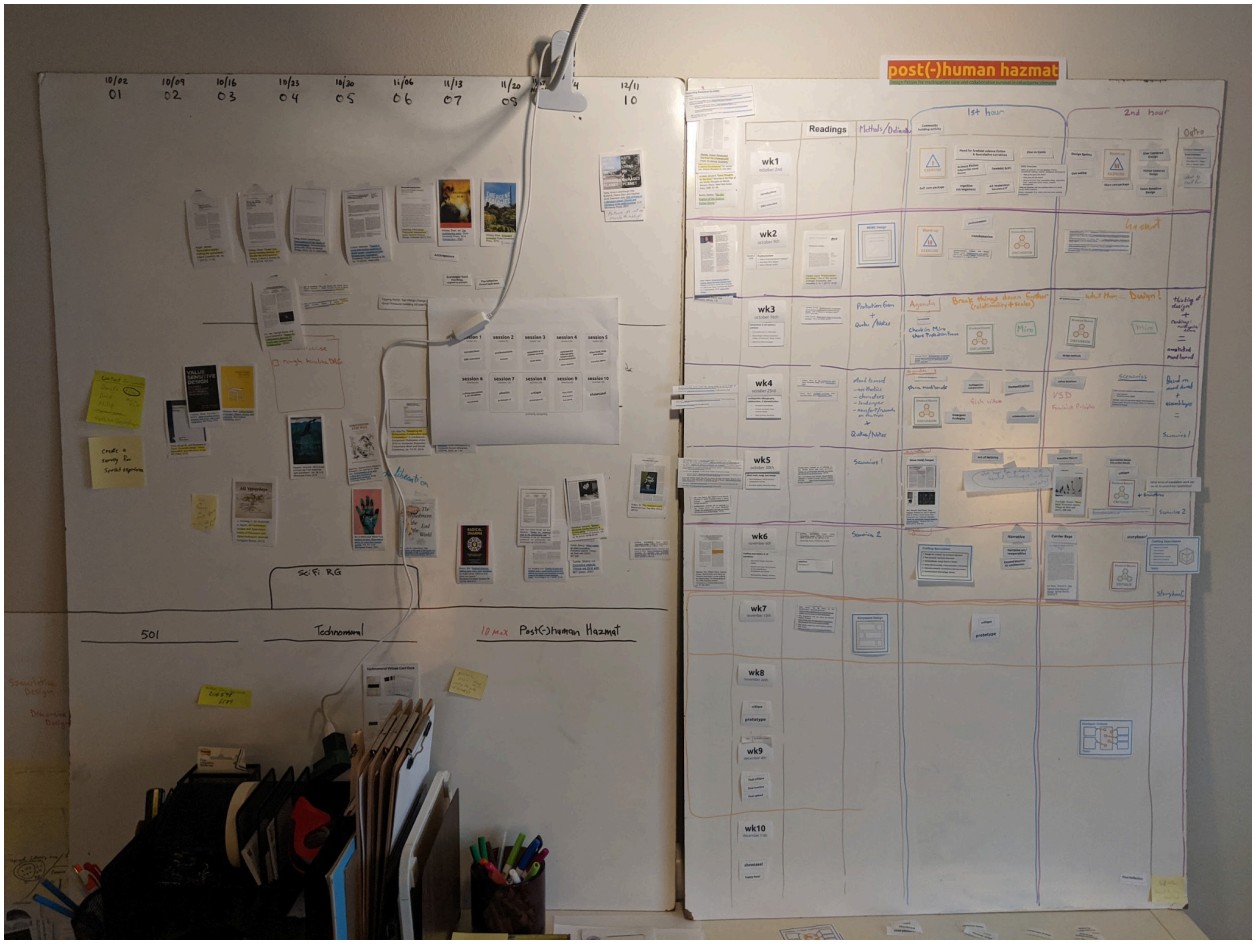

Figure 4.2. *Design process 2: Whiteboard where I designed the 10 sessions including readings and activities across each two-hour session and subsequent homework.*

Literature and Prior Work Informing the Design

The workshop design drew from three interwoven areas of scholarship: posthuman and feminist technoscience theory, value-sensitive and participatory design ethics, and speculative and discursive design practice.

Donna Haraway's *Staying with the Trouble* (2016)[141] and "Symbiogenesis, Sympoiesis, and Art Science Activisms for Staying with the Trouble" (2017)[142] provided conceptual grounding for sympoiesis, multispecies interdependence, and the holobiont as a lens for relational assemblages. Zakiyyah Iman Jackson's "Outer Worlds" (2015)[143] and Sylvia Wynter's

[141] Haraway, Donna J. 2016. Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.
[142] Haraway, Donna. "Symbiogenesis, sympoiesis, and art science activisms for staying with the trouble." Arts of living on a damaged planet (2017): M25-M50.
[143] Jackson, Zakiyyah Iman. "Outer Worlds: The Persistence of Race in Movement" Beyond the Human"." *GLQ: A Journal of Lesbian and Gay Studies* 21, no. 2 (2015): 215-218.

postcolonial critique of the category "human" (2003)[144] further complicated humanist assumptions and framed ontological "hazmat" as a site of racialized and colonial contamination. Laura Forlano's "Posthumanism and Design" (2017)[145] situated these debates within design research, calling for an expanded account of agency and relationality.

The workshop also incorporated James Auger's six tenants for crafting speculation (2013)[146] and Ursula K. Le Guin's "The Carrier Bag Theory of Fiction" (2019)[147] as an example to establish speculative storytelling as a method of ethical worldmaking. Value-Sensitive Design (VSD) principles (Friedman et al.)[148] informed structured reflection on ethical and relational tensions. Finally, discursive design traditions (Dunne & Raby 2013)[149] informed how participants' artifacts could operate as cultural provocations rather than utilitarian solutions.

This combination of posthuman theory, speculative fiction, and value-sensitive frameworks shaped the curriculum as both critical inquiry and creative practice, inviting participants to confront the hazardous entanglements of human exceptionalism while experimenting with alternative ontologies of care.

Lab-Field-Showroom Environment

Following Zimmerman and Forlizzi's (2014)[150] guidance that RtD begins with fieldwork and studio exploration, the workshop functioned as a hybrid "lab-field-showroom" environment (Koskinen et al., 2011).[151] It merged seminar-style readings and discussions (lab), collaborative online making (field), and a public showcase of artifacts (showroom).

Because the workshop took place entirely online during the COVID-19 pandemic, fieldwork unfolded synchronously over Zoom. Participants and facilitator engaged in collective reading, visual experimentation, and iterative prototyping using shared platforms such as Miro, Pinterest, and Google Drive. These tools functioned as the studio and archive

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[144] Wynter, Sylvia. "Unsettling the coloniality of being/power/truth/freedom: Towards the human, after man, its overrepresentation—An argument." *CR: The new centennial review 3*, no. 3 (2003): 257-337.
[145] Forlano, Laura."Posthumanism and design. "She Ji: The Journal of Design, Economics, and Innovation 3, no. 1 (2017): 16-29.
[146] Auger, James. "Speculative design: crafting the speculation." *Digital Creativity* 24, no. 1 (2013): 11-35.
[147] Le Guin, Ursula K. "The carrier bag theory of fiction." *The ecocriticism reader: Landmarks in literary ecology* (1996): 149-154.
[148] Friedman, Batya, and David G. Hendry. Value Sensitive Design: Shaping Technology with Moral Imagination. Mit Press, 2019.
[149] Dunne, Anthony, and Fiona Raby. Speculative Everything: Design, Fiction, and Social Dreaming. MIT press, 2013.
[150] Zimmerman, John, and Jodi Forlizzi. "Research through design in HCI." In Ways of Knowing in HCI, pp. 167-189. New York, NY: Springer New York, 2014.
[151] Koskinen, Ilpo, John Zimmerman, Thomas Binder, Johan Redstrom, and Stephan Wensveen. "Design research through practice: From the lab, field, and showroom." IEEE *Transactions on Professional Communication* 56, no. 3 (2013): 262-263.

of the research. Each week, participants documented reflections in a shared Virtual Notebook, responding to prompts such as “How do your stories incorporate theoretical frameworks?” and “What new meanings emerge in your narrative about multispecies relationships?”

This studio fieldwork foregrounded reflection-in-action: the design of prompts, digital materials, and weekly themes shifted in response to student engagement and emergent questions. As facilitator, I iteratively adjusted readings, exercises, and critique structures to maintain a balance between conceptual provocation and creative openness.

Participants, Structure, and Format of the Workshop

Participants included eleven University of Washington students (two MS, nine BS) from Human Centered Design & Engineering and related programs. The virtual format allowed for asynchronous engagement with materials and continuous documentation across platforms. The workshop met weekly for ten two-hour sessions via Zoom in Autumn quarter (September-December) of 2020. Each session combined concept discussions, design activities, and critique.

Table 4.1 (below) provides the workshop schedule including the theme and topics covered in each session and the to provide conceptual grounding and the structure followed a cumulative arc that began with conceptual grounding and moved toward collaborative production. Figure 4.3 (below) shows a screenshot of the schedule slide.

Table 4.1: *Post(-)human Hazmat Workshop Schedule.*

Session	Themes/Topics	Core Readings & Activities
1	**Introduction** Overview of goals of the workshop and concepts: zine, speculative design, speculative fiction, subjunctive mood, novum, cognitive estrangement.	No readings due before the first session.
2	**Posthumanism** + What is Post(-)humanism? Critiques? + How does it fit in design? + How is “hazmat” useful?	Forlano (2017)[152] Create a meme or “political cartoon” inspired by the reading.
3	**Sympoiesis & Art Science Activism**	Haraway (2017)[153]; Thurtle (2020)[154]

[152] Forlano, Laura."Posthumanism and design. "*She Ji: The Journal of Design, Economics, and Innovation* 3, no. 1 (2017): 16-29.
[153] Haraway, Donna. "Symbiogenesis, sympoiesis, and art science activisms for staying with the trouble." *Arts of living on a damaged planet* (2017): M25-M50.
[154] Thurtle, Phillip. “What does it mean to be human, anyway?” Henry Art Gallery (2020).

	+ From posthuman to relationality + Visual design methods (Illustration, collage, photography), Design critique + Axioms as titles & concepts	Add to Virtual Notebook: + Quotes/Notes of the readings + Sketch: "Protection from anxiety" card
4	**Multispecies Salon & Value Tensions** + Entangled assemblages, multispecies ethnography + Feminist principles, Value sensitive design, + Value tensions, Scenarios	Kirksey (2014 introduction)[155] Add to Virtual Notebook: + Quotes/Notes of the readings + Annotated moodboard
5	**Slime Mold, Fungi & Design** + Plant intelligence, Collaborative survival, "Art of noticing" + Evocative objects, Discursive design	Muindi & Muindi (2020)[156]; Liu et al. (2018)[157] Add to Virtual Notebook: + Quotes/Notes of the readings + Sketch 3-5 additional more-than-human value tension scenarios with written statement
6	**Crafting Speculation & Alt Narratives** + Speculative design, Discursive design, + Narrative arc types: hero's journey vs non-climactic arcs, temporalities, alt-binaries + Storyboarding, Ideation, Direction	Auger (2013)[158]; Le Guin (2019)[159] Add to Virtual Notebook: + Quotes/Notes of the readings + Assess your scenarios using the key factors from the Auger reading
7	**Plastics** Prototype V1	Articles on plastic ecologies[160] Add to Miro Board 08: 1. Identify your idea for final project 2. Create low-fidelity storyboard for final project 3. Outline your artist statement + Identify stakeholders, landscapes + Identify the value tensions + Identify theories/concepts
8	**Critique** Prototype V2	Peer feedback and iteration on final zine stories
9	**Finalize Zine** Final Critique, final adjustments, final upload	Digital compilation and layout of collective zine.
10	**Showcase & Reflection** Afterwards: final reflection	Public Zoom event with discussion among student-designers and audience.

[155] Kirksey, Eben, ed. *The multispecies salon*. Duke University Press, 2014.
[156] Ylfa Lund Muindi and Muindi Fanuel Muindi. "Episode 3." (2020) Forested Niches: A Nature Podcast. https://www.forestedniches.org/ (Fungal navigation)
[157] Liu, Jen, Daragh Byrne, and Laura Devendorf. "Design for Collaborative Survival: An Inquiry into Human-Fungi Relationships." (2018).
[158] Auger, James. "Speculative design : crafting the speculation." *Digital Creativity* 24, no. 1 (2013): 11-35.
[159] Le Guin, Ursula K. "The carrier bag theory of fiction." *The ecocriticism reader: Landmarks in literary ecology* (1996): 149-154.
[160] Wait, Plastic Can Be Good for the Environment? - Scientific American.; Why Bioplastics Will Not Solve the World's Plastics Problem.; Why plastic waste is an ideal building material - BBC Future.

Figure 4.3: *Screenshot of the Post(-)human Hazmat Workshop Schedule Slide.*

Materials, Prompts, and Activities

The workshop used multimodal materials to bridge theory and design practice:

- **Digital Platforms**: Zoom (for meetings), Miro (for collaborative boards and critique), Google Drive (for shared readings and submissions), Pinterest (for aesthetic inspiration), and a Virtual Notebook (for ongoing reflection).
- **Core Texts**: Forlano (2017); Haraway (2017); Kirksey (2014); Liu et al. (2018); Auger (2013); Le Guin (2019).
- **Design Prompts**: Weekly creative assignments translated theoretical readings into making activities—such as designing a meme that critiques anthropocentrism, sketching "value tension scenarios" among humans, plants, and technologies, and storyboarding speculative futures where care practices reconfigure multispecies relations.
- **Artifacts**: Participants produced iterative sketches, digital collages, and narrative prototypes culminating in a collaboratively edited digital zine.

Miro boards for weekly reading and discussion. Screenshots of the Miro boards from the weekly reading discussions during sessions 2-6 (see Figures 4.4–4.8) illustrate how participants collectively evaluated and synthesized the theoretical material. Each session included a shared digital workspace with prompts such as What resonates with you?, What

tensions or contradictions do you notice?, and How might this concept shift how you design? Participants added color-coded sticky notes to these boards to mark ideas, quotes, or questions that stood out to them. Over time, these visual traces became a form of communal reflection, revealing which concepts most strongly influenced participants' subsequent storytelling and design decisions.

Each session concluded with a short debrief inviting participants to articulate conceptual takeaways and aesthetic or ethical tensions encountered during making.

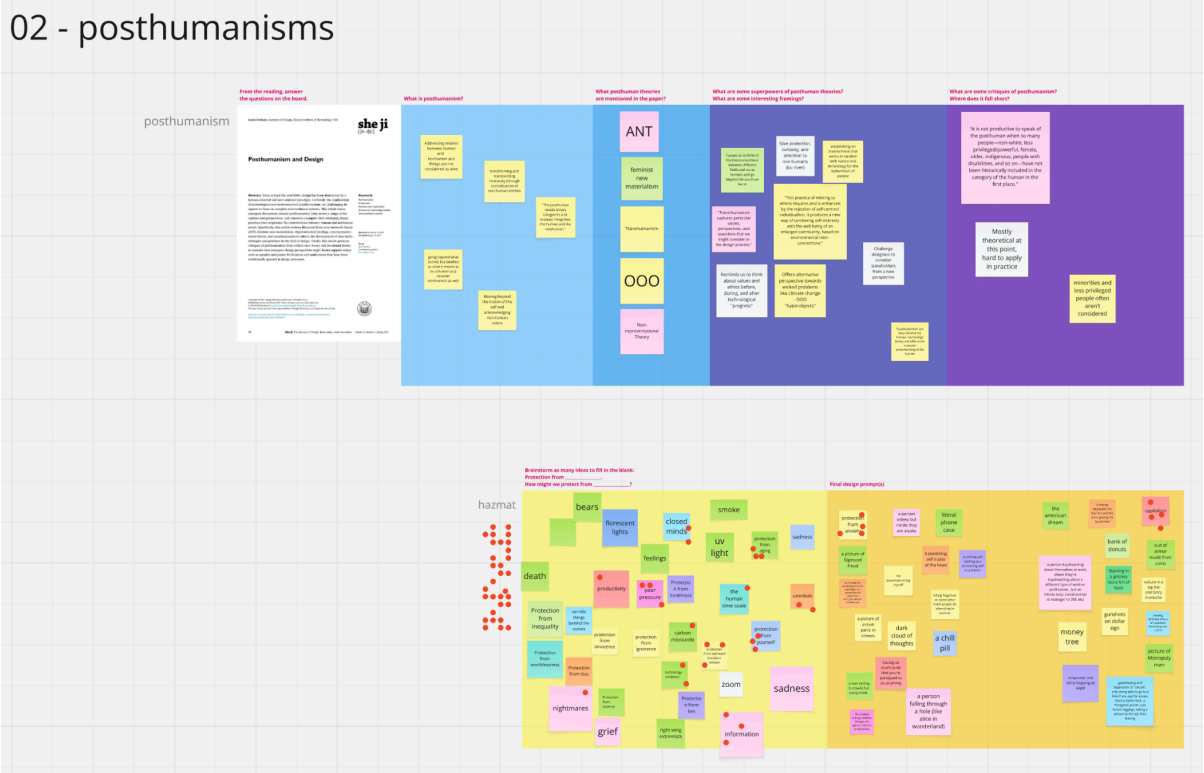


Figure 4.4: *Screenshot of the Miro board used for reading discussion, session 2: posthumanisms.*

Figure 4.5: *Screenshot of the Miro board used for session 3: sympoiesis & art science activism.*

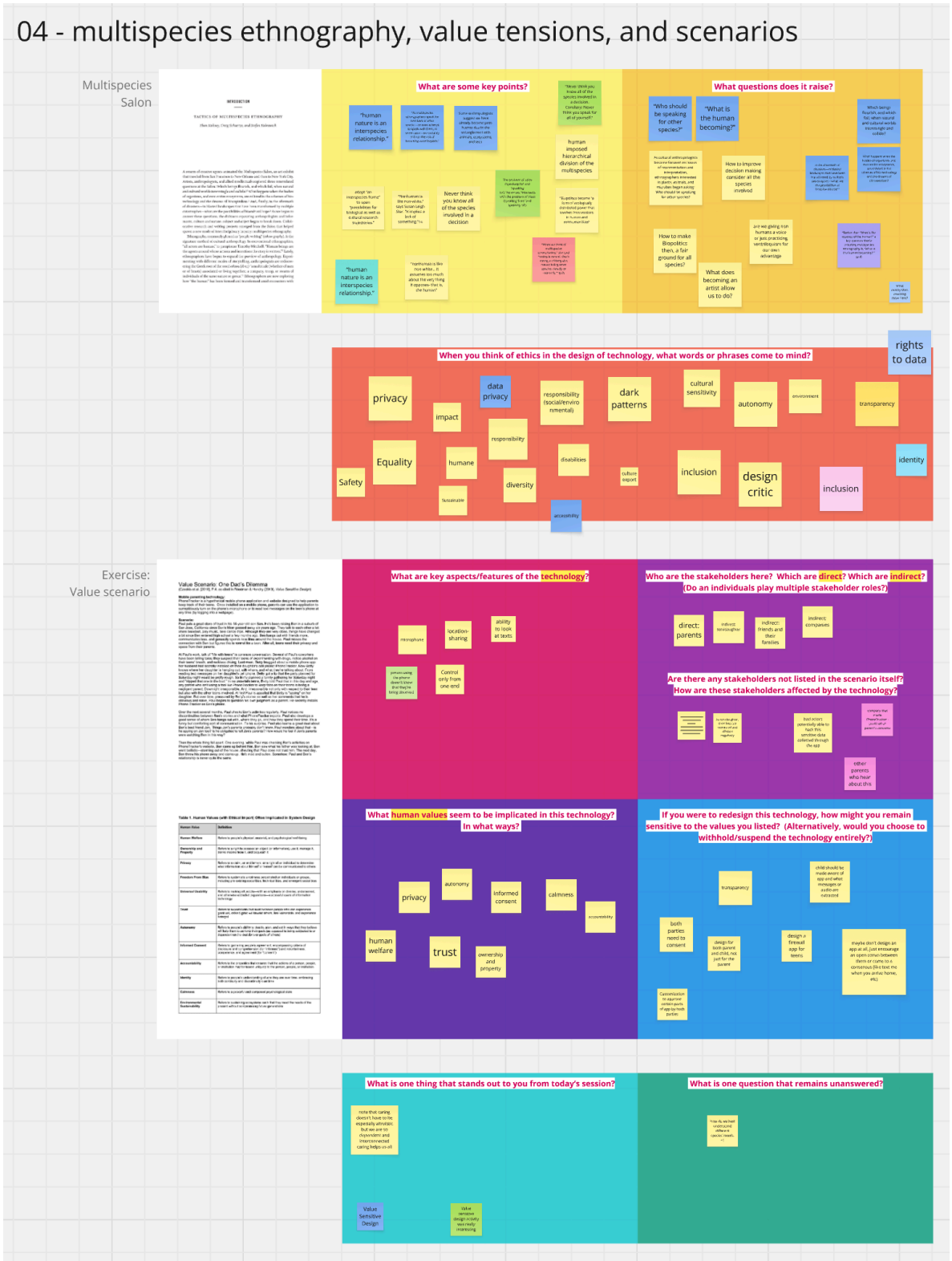


Figure 4.6: *Screenshot of the Miro board used for session 4: multispecies ethnography, value tensions & scenarios.*

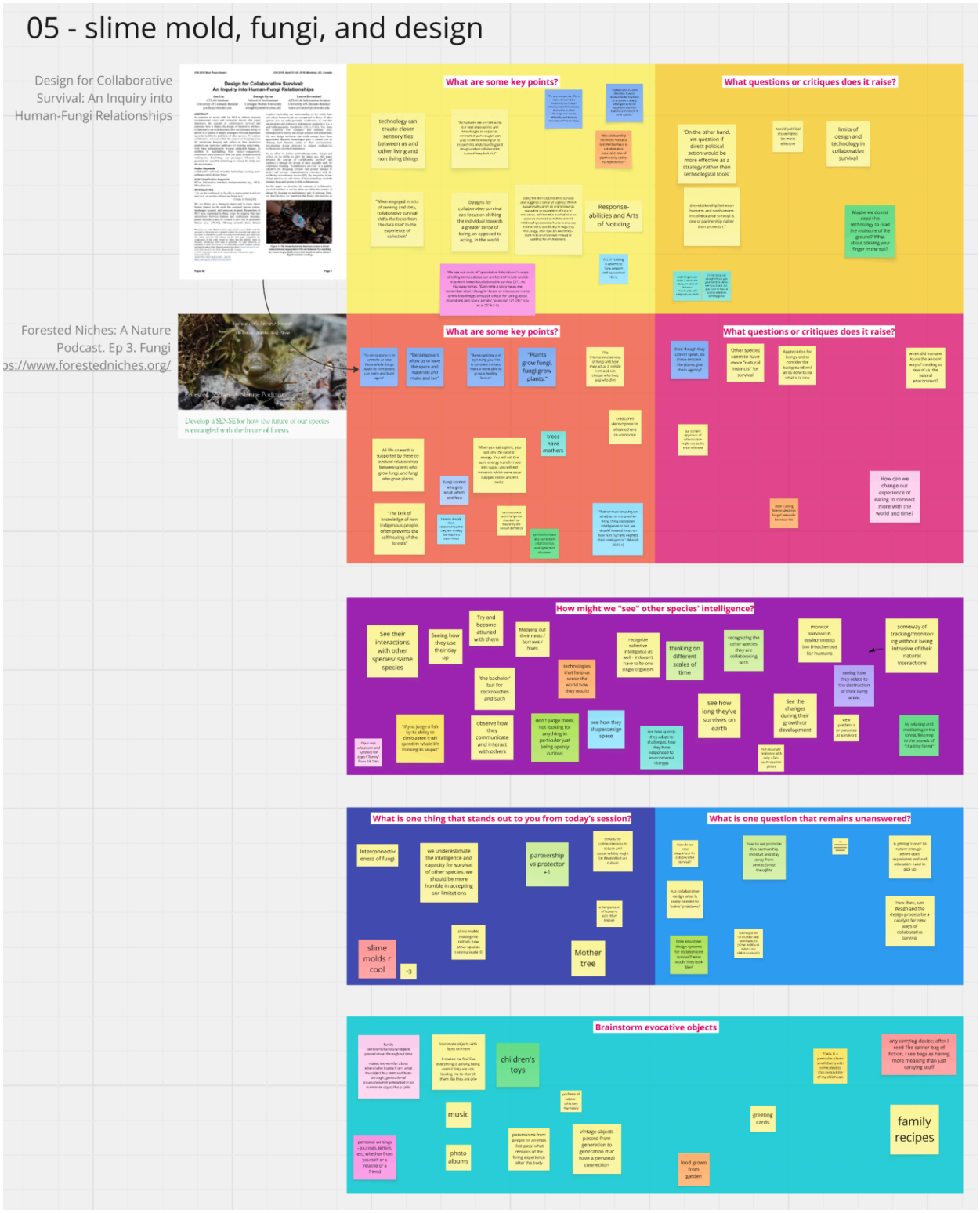


Figure 4.7: *Screenshot of the Miro board used for session 5: slime mold, fungi, and design.*

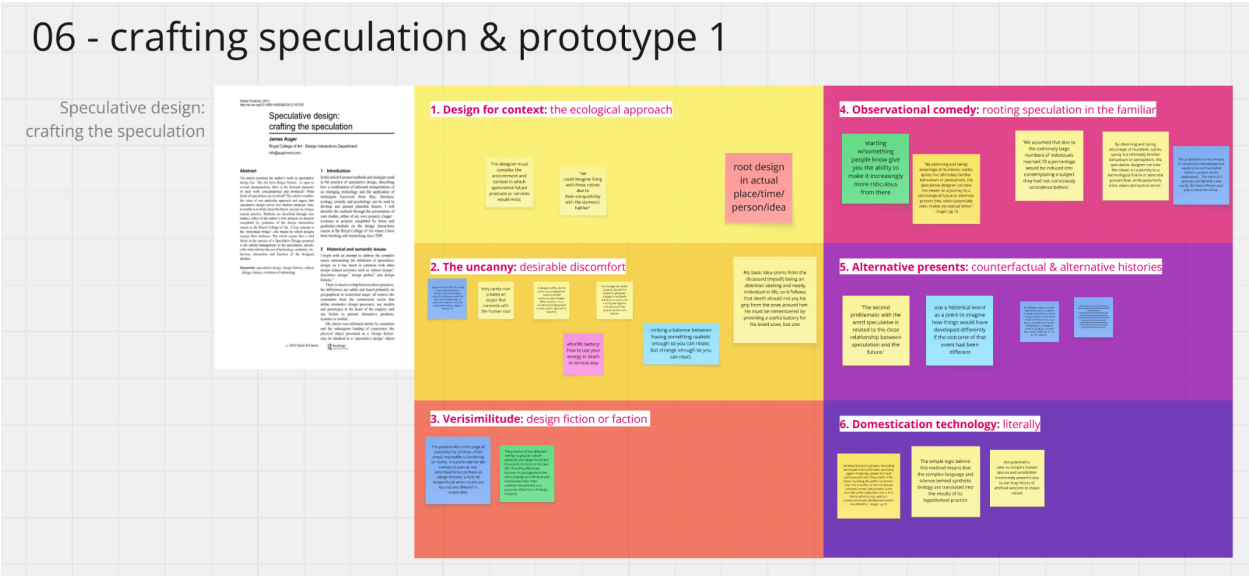


Figure 4.8: *Screenshot of the Miro board used for session 6: crafting speculation & prototype 1.*

Miro board for storyboards. To guide participants in translating theory into narrative form, I provided a storyboard scaffolding template on Miro (see Figure 4.9, below). This blank framework offered a common structure for participants to sketch their first story iterations. The template also included space for participants' feedback requests and peer-reviewed feedback.

Figure 4.9: *Screenshot of the Storyboard Scaffolding on Miro*

Step 3: Evaluate

Evaluation in *Post(-)human Hazmat* unfolded through two complementary layers: participant peer review and facilitator reflection. The workshop's structure was intentionally designed so that participants would act as evaluators of one another's speculative narratives, while I, as facilitator-researcher, evaluated the process as a whole,

monitoring patterns in engagement, quality of critique, and conceptual uptake in order to adapt the following sessions.

The first layer of evaluation occurred through ongoing peer-review sessions, where participants shared drafts of their speculative stories and offered each other feedback. Each week's readings introduced new concepts that participants were invited to integrate into their stories. During critique, peers discussed how effectively each story engaged these ideas, asking questions like: What further trouble or ethical tension could this narrative surface? or How might this character's relationship with nonhuman entities reveal a new mode of care? Through these exchanges, participants collectively developed evaluative criteria rooted in the workshop's theoretical provocations rather than formal design metrics.

The second layer of evaluation was my continuous reflection as designer and facilitator. After each session, I reviewed the feedback patterns on Miro, noting which theoretical ideas resonated, where confusion persisted, and whether participants were stretching their narratives conceptually. These observations guided adjustments to subsequent sessions sometimes shifting the emphasis of readings, adding framing questions, or redesigning activities to deepen engagement. For example, when early peer critiques focused narrowly on plot or visual style, I introduced prompts that explicitly linked story elements to value tensions and more-than-human ethics. This adaptive approach aligns with the reflection-in-action central to RtD, where facilitation itself becomes a design material shaped by ongoing evaluation.

Together, these two evaluative modes created a feedback ecology: participant critique generated insight and momentum within the cohort, while facilitator reflection ensured the curriculum continued to provoke conceptual and ethical growth.

Artifacts, Outputs, and Interpretation

The main artifacts produced through the workshop were the participants' speculative stories and the collaboratively assembled Post(-)human Hazmat Zine. Each story acted as both an outcome and an evaluative probe, testing how theoretical ideas could materialize in narrative and visual form. Over three weeks of iteration, participants posted successive versions of their stories to shared Miro boards. Each board accumulated colored sticky-note comments, sketches, and references from peers (see Figures 4.10–4.12, below), making visible how participants incorporated new concepts, increased design fidelity, and responded to critique.

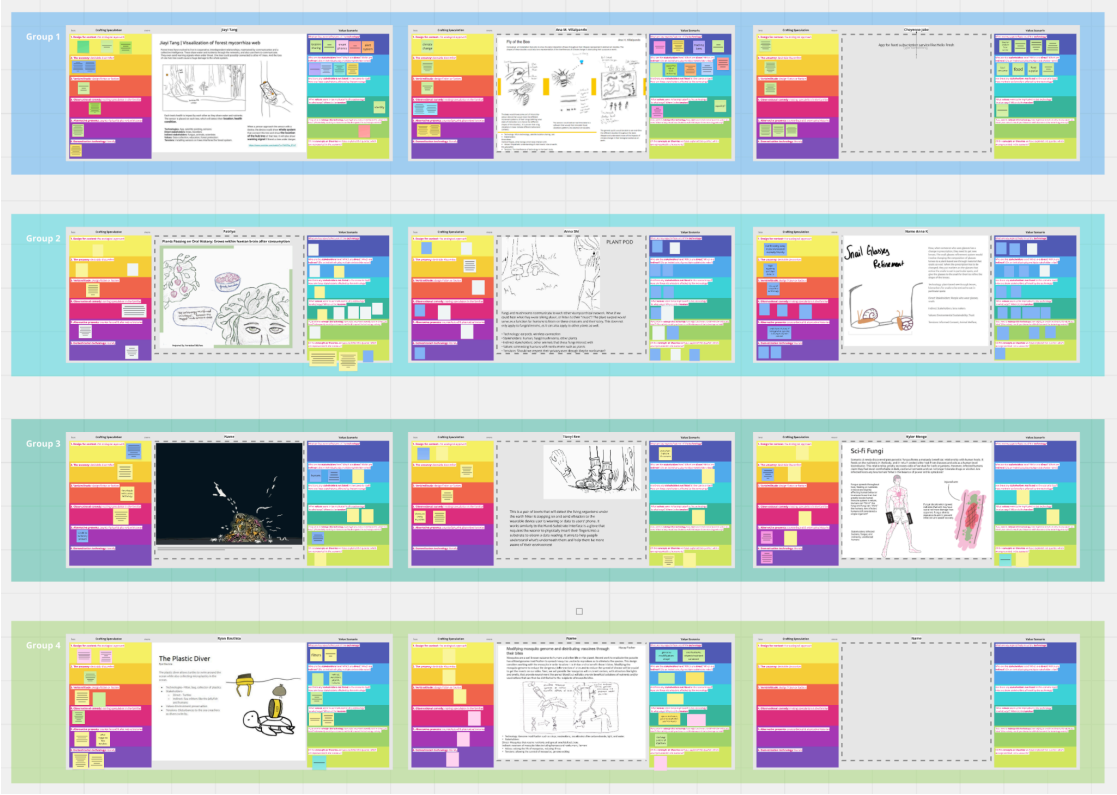


Figure 4.10. *Screenshot of the Miro board with participants' first iteration.*

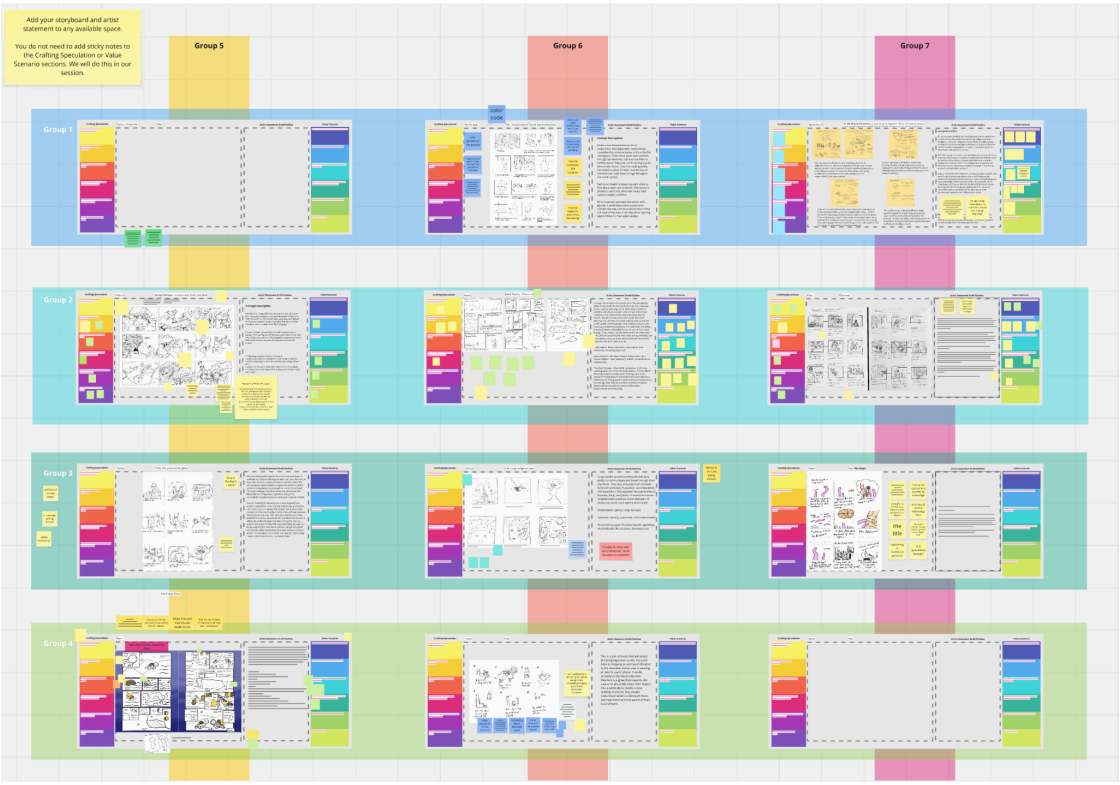


Figure 4.11. *Screenshot of the Miro board with participants' second iteration.*

Figure 4.12. *Screenshot of the Miro board with participants' third iteration. Three examples shown.*

While the peer review layer focused on expanding the conceptual richness of each narrative, the facilitator layer evaluated the collective trajectory of learning. I examined the emerging content of Miro discussions and the depth of participants' reflections to assess whether the workshop activities were fulfilling their goals of translating theory into practice. When feedback loops appeared to stagnate, e.g., when participants agreed too

readily, I intervened by reframing the next activity to re-introduce productive tension or alternative perspectives.

The Showcase. The final public showcase extended this evaluative framework outward. Participants presented their completed stories to an invited audience whose comments on Miro provided an additional interpretive layer (see Figures 4.13, below). These responses not only assessed the communicative success of the artifacts but also tested their ability to provoke new questions about multispecies care and posthuman design.

Figure 4.13. *Screenshot of the Showcase Miro board with participants' final stories.*

Post-Workshop Interviews

Six semi-structured interviews were conducted with students to examine how discursive and speculative practices were taken up in a 10-week design research group. Transcripts were coded for recurring themes, with particular attention to participants' characterizations of scope, method, transfer to human-centered design, and values. Participants characterized these practices as widening temporal horizons, enabling bolder inquiry, and foregrounding values and ethics within and alongside human-centered design. Tensions surfaced around approachability, production expectations, and institutional or industry pressures. Scope and time constraints were common. Participants also described learning amplified by collective exhibition and, in some cases, by connecting speculative work to community-facing concerns.

Calls to expand the remit of design beyond near-term problem solving recur across HCI and design research. The interviews analyzed here capture how design students articulated that expansion when learning and practicing discursive and speculative approaches in the workshop.

Insights from the interviews

Discursive and speculative work widened temporal horizons. Participants repeatedly linked discursive practice to thinking beyond immediate deliverables. One participant described speculative design as a way to "look beyond the immediate goal and look towards, like, how it could change society, or whether it'll be like, sustainable 50 years" and summarized the main lesson as "thinking short term versus long term." Another participant framed earlier experiences of speculative design as "very techno centric" and described a deliberate shift, stating an intent "to show that like, speculative design can be more than just technology."

A permissive studio ethos enabled bolder inquiry. Participants contrasted the latitude of the research groups with more constrained coursework. One participant emphasized that projects in the groups felt "more encouraging. Like, it's less limiting, at least for my like, design and imagination." Another participant highlighted a recurring studio prompt: "[Mentor] would always say make it weird" and connected that ethos to resisting a default toward polished outputs: "with user centered design, I think we're so worried about making something pretty and beautiful."

Tensions with UCD and HCD concerned approachability, prescription, and production. Participants identified frictions between discursive aims and conventional process or output expectations. One participant observed that user-centered design "can be very prescriptive" and contrasted that with discursive practice that "really makes you stop and think." Another participant connected this to decisions not to produce: "sometimes the best thing to do is not create something." Another participant pointed to methodological drift, noting that approaches "originative, or like meant to be more discursive or generative… are kind of appropriated into serving industry needs," citing cultural probes used "for, like a usability study."

Transferring speculative approaches to mainstream practice focused on ethics, unintended consequences, and early-stage framing. Participants reported carrying discursive sensibilities into ideation and evaluation. One participant articulated a concrete transfer: "One, definitely explore unintended consequences" and later reiterated that discursive work "helps with… exploring unintended consequences" by visualizing them. Another participant emphasized designer agency beyond reading off user needs, arguing that "good designers… need to give our own input."

Values work was present but unevenly explicit. Participants recalled explicit values-oriented activities and discussions, alongside occasional uncertainty about

provenance. One participant described integrating Value Sensitive Design (an approach that was introduced to them in the research group) into their capstone project: it "helped us figure out what we wanted to do as a brand" and to clarify "the mission of our team, our project… core values moving forward." Another participant confirmed values-oriented efforts, recalling "a story about a parent and their child…[being] really helpful."

Scope and time were persistent challenges. Participants highlighted the difficulty of scoping speculative worlds and executing within academic timelines. One participant wished for "more time to work on my projects" during the quarter and described the work as "time consuming… with all the right readings and producing something that's very ambiguous," agreeing that "maybe scoping is like a challenge."

Collective exhibition and juxtaposition amplified learning. Seeing multiple artifacts together made differences in framing legible and energized reflection. One participant described the culminating display: "seeing them all, like next to each other, too. It just feels really rich… with everyone's… perspective and energy."

Approachable formats supported broader engagement. Participants noted that some outputs made speculative work legible to non-specialists. Comparing formats across their experiences during their time at university, one participant remarked that "this zine format was the most successful one," reporting that "friends that I invited to the final showcase, they really enjoyed it."

Ethical reflection encountered organizational and sponsor pressures. Participants described reflecting on boundaries and grappling with sponsor expectations. One participant narrated an attempt to keep a project "on the ethical terms," then acknowledged a compromise: "I think I just have to… give a little bit of what Microsoft wants to hear… [to] make my work more like portfolio worthy at some point." In a related reflection on boundaries, they asked, "can we really push those boundaries… how can I put myself in those, like more ethical boundaries."

…

Across interviews, participants depicted discursive and speculative practice as a means to decenter immediacy and to interrogate assumptions. Participants consistently connect these practices to thinking in longer time frames, anticipating unintended effects, and raising ethical questions within and adjacent to human-centered design. Frictions centered on prescription and production orientation in standard processes, as well as on institutional and industry demands that could narrow or redirect ethical ambition. Reports of uneven explicitness around values indicate a role for clearer scaffolds that consistently surface value tradeoffs across activities. The salience of collective exhibition suggests that

juxtaposition operates as a pedagogical device for comparative learning. Approachable formats, including zines, appear to mediate speculative and discursive ideas to broader audiences.

Several actionable implications follow from what participants said. First, program structures that make time for exploration, or that stage iterative scoping, may reduce the mismatch between discursive breadth and academic timelines. Second, explicit value-mapping exercises and repeated return to those maps during critique can help keep values visible across the arc of a project. Third, approachable dissemination formats can extend the reach of discursive work beyond specialist audiences. Finally, acknowledging organizational realities while equipping students with strategies for articulating and defending ethical boundaries may help them navigate sponsor contexts. Limitations: This analysis reports only what participants stated and only includes claims supported by the transcripts. The interviews represent a single institutional setting and a small sample.

Shifting Framing and Evaluation Across Lab–Field–Showroom

Evaluation unfolded across the Lab–Field–Showroom continuum (Koskinen et al., 2011). The Lab dimension appeared in the structured experimentation with readings and design activities; participants tested how theoretical ideas could materialize in narrative form. The Field component emerged through collaborative engagement on digital platforms, where social, cultural, and ethical negotiations played out in real time. The Showroom moment occurred in the final public showcase, transforming the workshop into a site for audience reflection and dialogue about posthuman care and speculative ethics.

Tensions and Unexpected Dynamics

Several tensions emerged during the evaluation process. Some participants expressed uncertainty about how far to push speculative scenarios without losing coherence, while others wrestled with the discomfort of decentering the human perspective in their narratives. This was a realization that consistently decentering the human takes practice.

Rather than aiming for resolution, the evaluation process embraced these frictions as indicators of active engagement. They revealed that speculation, like wicked problems, do not operate through closure but through continual troubling, a principle that guided the next investigation, Speculative F/Actors, where collaborative worldbuilding extended these questions beyond individual narratives toward collective imaginaries.

Step 4: Reflect and Disseminate

The most significant insight that emerged from the workshop was that 'staying with the trouble' is a challenging practice that requires well designed support both in facilitation and scaffolding for crafting experience that allow discomfort, confusion, and disagreement to become productive sites of learning. As the facilitator, I came to understand that designing for entangled speculation requires balancing provocation with support. Early in the workshop, several participants expressed disorientation when confronted with dense theoretical texts or open-ended prompts. Instead of reducing this complexity, I adjusted prompts, pacing, and framing questions to help participants dwell meaningfully within uncertainty. This reframing marked an important methodological insight that contributed to the development of my facilitation practice in workshop design.

Conceptual and Methodological Insights

Conceptually, the investigation demonstrated how speculative storytelling can enact posthuman and more-than-human ethics by foregrounding care, relationality, and interdependence rather than technological progress or human mastery. The iterative and collaborative storytelling process showed that design fictions can function as ethical laboratories or spaces where values, relationships, and worldviews can be tested and reimagined.

Tensions and Unexpected Dynamics

Several tensions defined this investigation. Participants struggled initially to reconcile speculative openness with the perceived need for narrative coherence or design "solutions." Others expressed uncertainty about how to represent nonhuman perspectives without anthropomorphism. These challenges became central learning opportunities for the participants and for me as I think through designing the workshop activities. They exposed how deeply human-centered habits persist in design, even within explicitly posthuman framings, and how speculative storytelling can surface these assumptions for collective examination.

From a facilitation standpoint, the digital format introduced both constraints and unexpected affordances. While remote collaboration sometimes muted spontaneous discussion, the shared Miro boards created an enduring record of each participant's changing thought process, enabling forms of reflection that might not have surfaced in an in-person studio setting. These conditions highlighted the value of synchronous speculation and digital traceability. These insights informed how I later designed the workshop environments in Speculative F/Actors and Entangled Justice.

Dissemination and Audience Response

The outcomes of this investigation were shared through multiple forms. The Post(-)human Hazmat digital zine functioned as both artifact and dissemination platform, circulating the participants' speculative stories to broader audiences online. The public showcase acted as a "showroom" in the sense described by Koskinen et al. (2011), enabling participants and guests to engage in dialogue about the ethical and ecological implications of the works. Audience comments reflected appreciation for the speculative depth of the stories and curiosity about how design education might more regularly include such posthuman framings.

Beyond the workshop, this investigation contributed to several scholarly outputs. Insights from the workshop informed the co-authored paper "Value Sensitive Speculative Design: Exploring More-Than-Human Relations in the Age of Climate Catastrophe" (Beach & Fox, 2022), published in Interaction Design and Architecture(s) Journal (IxD&A). Portions of the zine and process documentation were later exhibited in the HCDE's 2021 *Designing Up* magazine.[161]

Step 5: Repeat

The reflections and tensions that surfaced in *Post(-)human Hazmat* directly informed the design of my next investigation, *Speculative F/Actors: Climate Futures*. The challenges of translating dense theory into practice, sustaining conceptual depth within collaborative storytelling, and balancing openness with structure led me to reimagine how speculation could operate more collectively and in more grounded ways. In *Speculative F/Actors*, I shifted from individual narrative production toward shared worldbuilding, expanding the workshop's scope from personal interpretation to distributed, entangled speculation across participants and contexts.

[161] An article about the DRG was written for Designing Up magazine. See: https://www.hcde.washington.edu/designing-up/2021/post-human-hazmat

Chapter 5: Investigation 2 - Speculative F/Actors

Step 1: Select

This investigation builds upon the first study, *Post(-)human Hazmat*, which foregrounded speculative storytelling as a means for reflecting on multispecies care and individual sense-making. While *Post(-)human Hazmat* cultivated introspective, narrative forms of speculation, *Speculative F/Actors* extended the inquiry to explore shared realities and potential future scenarios through collaboration and material engagement. It asks how speculative worldbuilding can surface the interconnected dynamics of climate, ecology, politics, and technology. In doing so, it carries forward questions of how we might design for wicked problems.

This work responds to the increasing urgency of environmental crises, which are entangled with complex sociotechnical, political, and ecological dynamics. From the existential threat of climate collapse to the rise of artificial intelligence and geopolitical unrest, participants today navigate a world of interrelated, often overwhelming challenges, what is referred to as "wicked problems" (Irwin, 2015; Rittel & Webber, 1973).[162] The workshop addresses this by inviting participants to co-design a diorama of the future while making sense of how climate futures are shaped not only *by* human decisions but *through* interactions among diverse F/Actors: political institutions, infrastructures, species, and ecological forces.

Why was this particular site, theme, and provocation chosen?

The design of *Speculative F/Actors* draws upon the same three overlapping but distinct areas of study from the first investigation: Posthumanism, Design Justice, and Entanglement.

[162] Irwin, Terry. 2015. Transition design: A proposal for a new area of design practice, study, and research. *Design and Culture* 7, 2 (2015), 229-246.; Rittel, Horst WJ, and Melvin M. Webber. "Dilemmas in a general theory of planning." *Policy sciences* 4, no. 2 (1973): 155-169.

These literatures frame speculation as both an epistemic and ethical practice that embraces uncertainty, affect, and the political stakes of imagining futures.

This intervention was motivated by both conceptual and practical goals. Conceptually, it seeks to explore how speculation could serve as a relational design practice, enabling participants to engage with the political, material, and affective dimensions of climate futures. Practically, it seeks to create a collaborative space for discussing wicked problems (in this instantiation, climate change), be accessible to a range of participants, and be adaptable to different contexts.

The theme of Climate Futures was selected to create a bridge between design speculation and public discourse on environmental change. The workshop has been deployed across multiple settings, including academic (SLSA conference), public (Pensacola Museum of Art), and internal pilot environments. These sites were chosen to test the workshop's adaptability across different levels of participant expertise and engagement. They also allowed us to explore how local context shaped speculative worldbuilding, particularly in how participants grounded their future visions in the ecological and political specifics of place.

How does this investigation continue the RtD cycle?

The *Speculative F/Actors* investigation advanced the RtD cycle by transforming the insights from *Post(-)human Hazmat* into a new workshop format centered on collective worldbuilding. In the first investigation, I learned that activities for "staying with the trouble" demand intentional design of both facilitation and scaffolding to help participants navigate productively through discomfort, confusion, and disagreement. I also found that designing activities for participants to have an in-depth engagement with theory effectively supported the initial goal in *Post(-)human Hazmat to* translate theory to practice, but it required significant time and commitment. This approach worked well in *Post(-)human Hazmat*, which unfolded over ten sessions, totaling twenty hours of synchronous work plus additional time for individual reading and design activities, but it would not be feasible in a shorter, two-hour workshop format. The third major insight from Post(-)human Hazmat concerned the locus of collaboration. In that workshop, participants independently translated theory into their own speculative stories, then shared and critiqued one another's narratives during group sessions. This format worked well for a recurring, multi-session setting, but it ultimately produced eleven distinct stories—each situated within its own imagined reality. Just as individuals experience different realities in everyday life, addressing wicked problems also requires constructing shared worlds of understanding. This realization led me to design the next investigation as a shorter, more collaborative workshop focused on collective and collaborative worldbuilding, creating new material prompts and facilitation strategies that supported shared exploration of uncertain futures.

Participants would bring their lived experiences, knowledge, and wisdom into conversation, co-designing a shared speculative future through dialogue and material engagement.

Step 2: Design

The first conception of *Speculative F/Actors* emerged in 2019, before *Post(-)human Hazmat*, as an experimental idea for a time-traveling diorama and research kit that could facilitate communication between one's present and future selves. It asked, "What do we need to know now to address the future?" The project was set aside and then revisited and heavily reimagined in 2021 using insights from the *Post(-)human Hazmat* investigation, where participants co-constructed speculative futures through dialogue and material engagement.

The iterative process of developing the workshop, including two pilot studies and subsequent workshops at Society of Literature, Science, and Arts (SLSA) in 2019 and the Pensacola Museum of Art (MoA) in 2022 that led to the final featured instantiation of the workshop (2023) that is introduced in the "Participants, Structure, and Format of the Workshop" section below.

Literature and Prior Work Informing the Design

This workshop draws on several conceptual foundations that foreground the relational, material, and speculative nature of climate futures. It is situated within the fields of speculative design, more-than-human design, and entanglement theory, while also being informed by feminist and justice-oriented critiques of participation and worldbuilding.

A central aim of this workshop was to encourage participants to think not just about what is probable, but about what is possible and preferable. This shift resonates with emerging discourse in HCI around design as a speculative and affective practice (Auger, 2013; Benabdallah, 2023; Tharp and Tharp, 2018),[163] and with Donna Haraway's provocation to "stay with the trouble" (2016)[164]—to remain present with the discomfort and complexity of systemic change rather than bypassing it.

[163] Auger, James. 2013. Speculative design: Crafting the speculation. Digital Creativity 24, 1 (2013), 11–35.;
Gabrielle Benabdallah, Michael W. Beach, Lucy Suchman, Kavita Philip, Nathanael Elias Mengist, and Daniela Rosner. (2023). "The Politics of Imaginaries: Probing Humanistic Inquiry in HCI." Designing Interactive Systems (DIS), Carnegie Mellon University, Pittsburgh, Pennsylvania..
Tharp, Bruce M., and Stephanie M. Tharp. 2018. Discursive Design: Critical, Speculative, and Alternative Things. MIT Press.
[164] Haraway, Donna J. 2016. Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.

From this foundation, five design principles were identified to structure both the workshop's material design and facilitation logic:

1. **Collaboration**: Emphasizing diverse backgrounds, perspectives, and lived experience to co-create future scenarios (Moirano, 2020; Simonsen and Robertson, 2012).[165]
2. **Troubling**: Encouraging participants to stay present in the complexities of climate issues, inspired by Haraway's concept of "staying with the trouble." (2016)[166]
3. **Speculation**: Fostering imagination of possible and potential more-than-human scenarios to identify new relations, evaluate risks and benefits, and consider possible responses (Malpass, 2019).[167]
4. **Entanglement**: Highlighting interconnectedness of systems, technologies, and more-than-human assemblages, acknowledging broader implications of design decisions (Frauenberger, 2019).[168]
5. **Situatedness**: Understanding and accounting for the specific social, cultural, and environmental contexts of participants and more-than-human factors and actors (Costanza-Chock, 2018).[169]

Ideation, and Early Prototypes and Workshops

Initial brainstorming sessions focused on integrating storytelling elements into the workshop. Challenges in balancing multiple factors (Auger, 2013)[170] led to exploring alternative storytelling techniques, such as card decks and dioramas (Artefact, 2023; Peters and Ahmadpour, 2021).[171] The first prototype was a low-fidelity kit using laser-cut chipboard elements and a mix of crafting materials (e.g., dice, moulding clay, plastic remnants, string, miniature trees) to facilitate diorama construction, and note cards for responding to prompts, see Figure 5.1 below.

[165] Moirano, Riccardo., María A. Sánchez, and Ladislav Štěpánek. 2020. Creative interdisciplinary collaboration: A systematic literature review. Thinking Skills and Creativity 35 (2020), 100626.; Simonsen, Jesper., and Toni Robertson (Eds.). 2012. Routledge International Handbook of Participatory Design. Routledge.
[166] Haraway, Donna J. 2016. Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.
[167] Malpass, Matt. 2019. Critical Design in Context: History, Theory, and Practice. Bloomsbury Publishing.
[168] Frauenberger, Christopher. 2019. Entanglement HCI: The Next Wave?. ACM Transactions on Computer-Human Interaction (TOCHI) 27, 1 (2019), 1-27.
[169] Costanza-Chock, Sasha. 2018. Design justice: Towards an intersectional feminist framework for design theory and practice. In Proceedings of the Design Research Society (DRS '18).
[170] Auger, James. 2013. Speculative design: Crafting the speculation. Digital Creativity 24, 1 (2013), 11–35. https://doi.org/10.1080/14626268.2013.767276
[171] Artefact. 2023. The Tarot Cards Of Tech. Retrieved February 1, 2023 from http://tarotcardsoftech.artefactgroup.com/ ; Peters, Loke D. and Nazanin Ahmadpour. 2021. Toolkits, cards and games–a review of analogue tools for collaborative ideation. CoDesign 17, 4 (2021), 410-434.

Figure 5.1. *Assembly of early material prototypes for the Speculative F/Actors kit.*

Pilot 1 (October 2019)

The initial pilot was conducted with departmental colleagues as seen in Figure 5.2, below. It included a 15-minute presentation prior to the workshop activities that sensitized participants to our theoretical foundations (including concepts from Simondon, the futures cone, and wicked problems) and introduced participants to the goals and materials of the workshop. The shift towards practical, material-based speculation was particularly successful. We refined our approach by reducing theoretical content and enhancing the hands-on, creative aspects with unconventional materials like trash and failed 3D prints.

Figure 5.2. *First pilot with departmental colleagues engaging with the Speculative F/Actors kit.*

Workshop 1 (SLSA, UC Irvine; November 2019)

During our first workshop (see Figure 5.3 below), with 15 participants, we found that reducing the amount of dense theory in the introduction presentation led to better participant understanding and a smoother and more focused engagement with the worldbuilding activities. Despite this, the mechanics of using test tubes proved too cumbersome, interrupting the flow of creative collaboration. This feedback led us to replace these elements with a more streamlined "vibe card," (a single card for participants to respond to all of the prompts). This adjustment enhanced the workshop flow while maintaining open-ended speculative dialogue for futurecasting questions (Irwin, 2015).[172]

Figure 5.3. *First workshop SLSA 2019. Participants filling out cards from the kit.*

[172] Irwin, Terry. 2015. Transition design: A proposal for a new area of design practice, study, and research. Design and Culture 7, 2 (2015), 229-246.

Pilot 2 (November 2022)

Our second pilot (Figure 5.4 below) focused on implementing changes prompted by previous feedback and insights from *Post(-)human Hazmat*, particularly around the form and engagement mechanisms of the workshop. We reduced the number of crafting materials, removed the test tube activity, and added strings to trace organic, technological, and political relations. The tracing activity was added to make the entangled relations more explicit to the participants. The post-pilot feedback discussion confirmed that our new direction supported more evenly distributed participant agency and engagement, and the simpler set of crafting materials were more effective in facilitating the dialogue around the interconnections of more than human factors and actors.

Figure 5.4. *Participant tracing entangled relations during the second pilot using colored pipe cleaners to map organic, technological, and political connections.*

Workshop 2 (MoA, Pensacola; December 2022)

Our second workshop (Figure 5.5 below), involving nine participants including museum staff and local professors, significantly refined our approach. We tailored the materials to include locally situated more than human factors and actors, such as local biota and other regional elements to facilitate more meaningful engagements. We worked with partners at the MoA to manufacture the laser cut materials locally, providing print files and process notes (see Figure 5.6 below).

Figure 5.5. *Workshop 2 at the Pensacola Museum of Art with nine participants engaging in localized worldbuilding using regionally adapted Speculative F/Actors materials.*

Figure 5.6. *Speculative F/Actors kit fabricated by partners at the Pensacola Museum of Art.*

The quality of dialogue and speculative interaction reached new heights, emphasizing that the value of these workshops lies more in the worldbuilding process and conversations than in the physical artifacts produced. The final iteration presented in this paper focuses on better capturing these discussions through audio and video recordings.

Lab-Field-Showroom Environment

Across its iterations, *Speculative F/Actors* engaged each mode of Koskinen et al.'s (2011) Lab–Field–Showroom framework to iteratively test and reframe its speculative design inquiry. In the Lab, early prototypes and pilots functioned as controlled experiments for exploring material configurations, facilitation cues, and participant comprehension. The Field emerged through public and institutional workshops, at the Society for Literature, Science, and the Arts (SLSA) conference and the Pensacola Museum of Art, where participants' diverse disciplinary and regional perspectives shaped new relational framings of climate futures. Finally, the Showroom dimension surfaced through a museum exhibition and a publication, where dioramas and string mappings were shared as a speculative mode of ethical imagination. Together, these environments produced a recursive learning loop: insights from the Lab informed real-world adaptations in the Field, while the public responses in the Showroom reframed subsequent workshop iterations.

Workshop Recruitment

For this final round of *Speculative F/Actors: Climate Futures* workshops, eight participants were recruited across academic networks within the University of Washington. Recruitment efforts focused in areas with diverse disciplinary backgrounds including my home department (HCDE), design, environmental studies, art, and the humanities. I sent recruitment materials to outreach coordinators in these departments directly via email, as well as community networks spaces including DUB (Design Use Build) Slack and HCDE Community Slack. The research team posted fliers in buildings across campus, including HUB (Huskey Union Building), Padelford, Suzzallo, Allen Library, Kane Hall, Odeggard, Savery, Mary Gates, Sieg, Paul Allen, and Anderson.

Recruitment messaging included a link and QR code to a digital signup form where participants could view available workshop dates and times and register for a session that suited their schedule. The invitation emphasized that no prior design experience was required, only an openness to creative collaboration and speculative thinking about climate futures.

All participants received information about the study and consented to participation. Consent forms included options for image use of workshop materials and photos. The project was approved under UW's IRB exempt status. These materials outlined the structure of the session, use of photographs and recordings, and voluntary participation terms. Workshops were scheduled based on participants' availability and conducted in a quiet, studio-like setting in Research Commons on the University of Washington campus.

Workshop Structure and Format

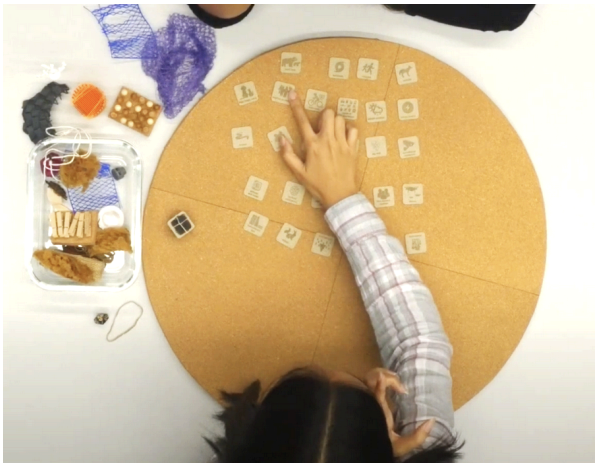
The final *Speculative F/Actors* workshop emphasized a new possibility-oriented mental model, encouraging participants to imagine climate futures not bound by dystopian inevitability but grounded in plausible alternative pathways. This final iteration was run three times: October 26, October 27, and November 2, 2023. Each workshop consisted of 2-3 participants sitting around a table with the *Speculative F/Actors* kit in the center of the table, with workshop slides projected on a screen.

The workshop unfolds through five structured steps, each designed to guide participants in worldbuilding and discussion. These steps gradually build in complexity, starting with identifying key factors and actors that exist in the present local scenario and culminating in the co-construction of speculative futures that trace salient political, technological, and organic relations.

THE WORKSHOP STEPS

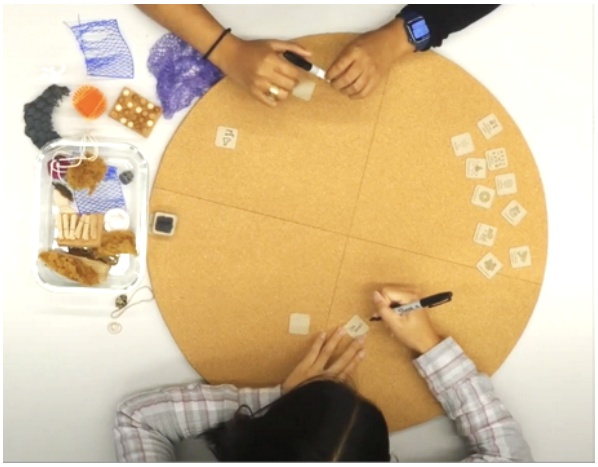
PRE-STEP: GROUP FORMATION

Form a group of 2-3 participants. Gather around a diorama board, with a stack of F/Actor tiles and other diorama materials ready. Walk participants through the following workshop activities.



STEP 1: TILE SELECTION

Participants deliberate and select 10 tile F/Actors that resonate most with the group, returning the remaining tiles to the kit box.



STEP 2: NEW F/ACTORS

Each participant writes in an additional tile F/Actor they feel is missing, considering elements like a specific technology, policy, community leader, organism, or socio-ecological force they wish to include.

STEP 3: CHANGE IN 50 YEARS

Participants select three F/Actors they believe will go extinct, disappear, or undergo dramatic change in 50 years, and then decide what will take their place.

STEP 4: DIORAMA OF THE FUTURE
Participants construct a diorama depicting the world 50 years into the future, arranging selected F/Actors tiles and other elements to bring the scene to life.

STEP 5: TRACE SALIENT RELATIONS
Participants use differently colored strings to map key political (orange), technological (blue), and organic (green) relations within the diorama. These traced connections become the basis for sharing and discussing insights and challenges encountered throughout the workshop.

Materials, Prompts, and Activities

The workshop kit included a diorama board made of cork, a set of laser-cut F/Actor tiles representing both abstract and specific entities, and blank tiles for participants to create new ones during the session. It also provided diorama construction materials for assembling scenes including natural materials (e.g., sponge, fibers) and plastic materials (e.g., remnants from 3D printed objects), colored string for mapping political, technological, and ecological relations, and optional location- or issue-specific add-ons tailored to each workshop location. Together, these tangible components provided goods for relational thinking and grounded abstract concepts in playful, concrete interactions. See materials in Figure 5.7 below.

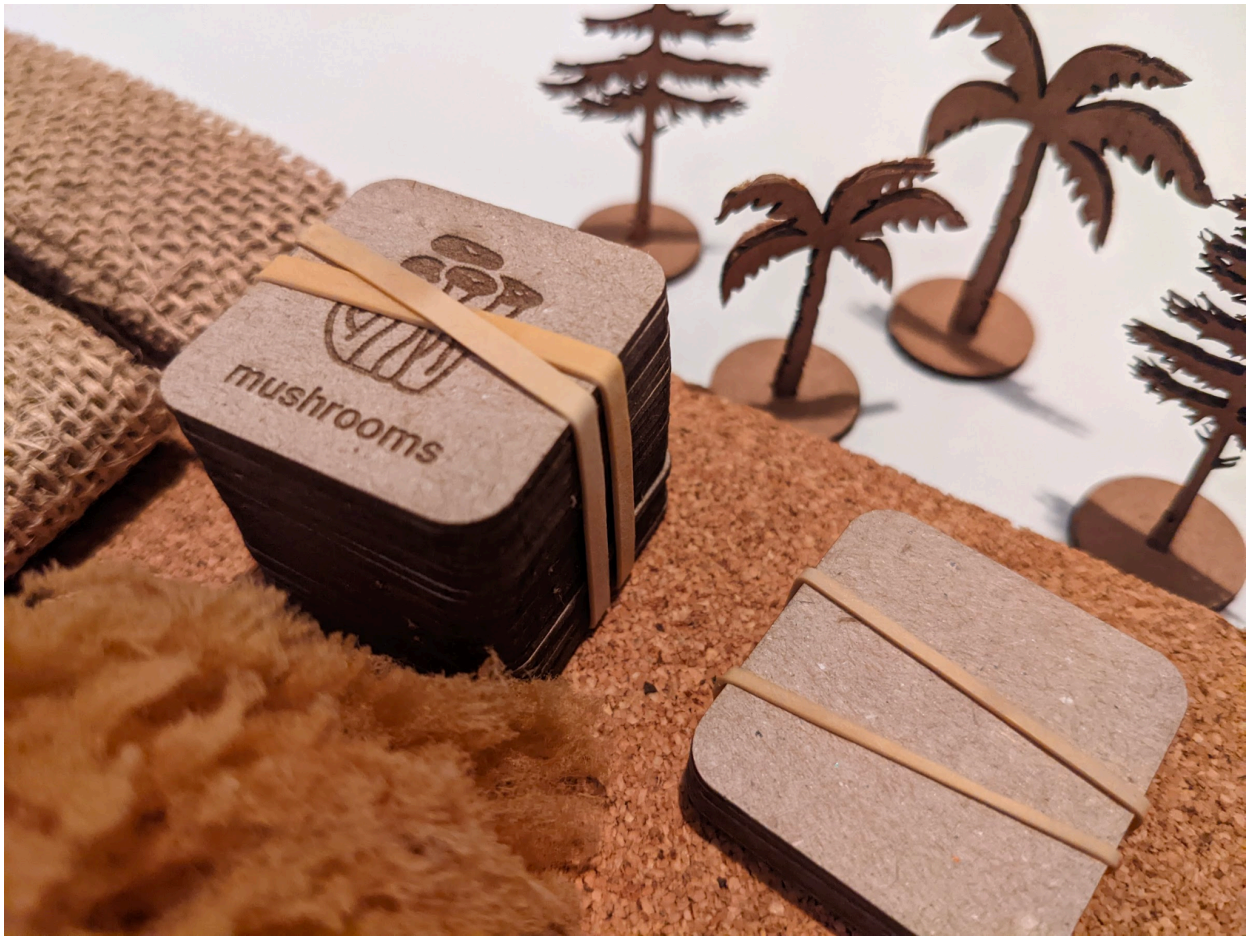


Figure 5.7. *Speculative F/Actors kit fabricated materials.*

The F/Actors Tiles. The workshop materials present participants with a set of small tiles (see examples on this page) introducing various factors and actors into the initial conversation. These tiles, which vary in specificity, generate discussions among participant groups about how to compare certain tiles (e.g., Policy and Policymakers), how to gather a diverse set of relevant tiles (e.g., living organisms, institutions, things, scientific developments), and how to work with tiles they find interesting, important, and relatable. Participants are asked to select a limited number of tiles to engage with during the workshop, discussion, and world-building activity.

In the first step of the workshop, participants are introduced to tiles representing various factors or actors, including societal institutions, key environmental and societal systems, specific human and non-human organisms, and fields of development and personnel. These tiles, designed to encompass key human and non-human entities, initiate relational discussions about the climate change landscape. This process allows participants to select the factors and actors that will serve as the primary components in their workshop.

The tiles range from abstract concepts like 'modes of transportation' to specific elements such as individual organisms (e.g., mushrooms) or scientific developments (e.g., CRISPR). This variation in specificity primes participants to consider inter-relational connections and how certain factors might interact and impact others. See tile set in Figure 5.8 below.

Figure 5.8. *Speculative F/Actors laser cut tiles.*

Step 3: Evaluate

Facilitation, Documentation, and Interpretation

Each workshop was audio- and video-recorded, and photographs were taken of the dioramas and string mappings. These materials were later reviewed to extract key themes, speculative moves, and relational framings. Post-workshop interviews, lasting approximately 30 minutes each, were transcribed and coded thematically, revealing shifts in participant understanding, engagement, and imaginative framing. See more about the research team and process in Chapter 3: Methods.

Artifacts, Outputs, and Interpretation

The *Speculative F/Actors: Climate Futures* workshop generated a variety of material and discursive outputs that served as both reflective tools and representational artifacts. These outcomes (including dioramas, relational string maps, emergent narratives, and participant commentaries) were not treated as polished deliverables but as provocations that exposed relational logics, imaginative tensions, and future-oriented desires.

The central artifact produced during each session was a collaborative diorama, composed of selected F/Actor tiles, participant-generated tiles, and construction materials such as natural textures, cardboard structures, found objects, and handwritten labels. These

physical compositions represented speculative futures set approximately 50 years ahead, allowing participants to visualize and materialize imagined ecosystems, societal shifts, technological adaptations, and more-than-human relations.

Following the construction of the collaborative diorama, participants used colored string to trace and map salient connections:

- **Orange** for political relationships (e.g., power, policy, governance)
- **Blue** for technological or infrastructural connections
- **Green** for bodily or ecological entanglements

These strings crisscrossed the boards, connecting actors across categories, and often illuminating non-obvious dynamics. In some cases, the process of string mapping prompted shifts in interpretation as participants paused, debated string placement, and reflected aloud on what their mappings revealed. For instance, one group mapped severe weather as a central node connected by green (ecological), orange (political), and blue (technological) strings which led to discussions of food insecurity and climate-induced migration.

While the dioramas served as anchors, the dialogues that unfolded during and after their construction proved equally generative. Participants articulated speculative stories about policy shifts, biological transformations, technological interventions, and communal adaptation. Some framed their futures as cautionary tales; others offered counter-narratives rooted in collective action and care.

These speculative narratives often challenged dominant framings of environmental discourse, moving beyond techno-optimist or apocalyptic binaries. Through dialogue, participants situated abstract systems such as surveillance capitalism, severe weather, or AI within lived and embodied experiences.

> "It was cool to look at the materiality of systems like policies and surveillance capitalism." (P4, Interview)

In the post-workshop interviews, participants reflected not only on what they had built, but on how the process shifted their thinking. Several commented on how visualizing interconnections made climate issues feel more immediate, tangible, and personally significant.

Insights from the workshop and interviews

While the dioramas themselves are ephemeral and open to multiple interpretations, their value lies in the thinking they provoked and the ways that physical placement, tactile engagement, and shared authorship fostered deeper inquiry into climate futures. We look at insights from the post-workshop interviews.

Participant Engagement and Dynamics

Participant engagement in the *Speculative F/Actors: Climate Futures* workshop demonstrated both the generative potential and emotional complexity of collaborative speculation. Across different sessions, participants navigated questions of agency, uncertainty, scale, and systemic change, bringing divergent viewpoints into conversation. These interactions highlighted the value of co-speculation as a relational, sometimes fragile, and always situated practice.

From Hesitation to Co-construction

Early stages in the workshop, participants often experienced moments of hesitation, especially when prompted to project 50 years into the future. Some asked whether they were meant to predict or hope:

> "Are we saying what we think will happen or what we want to happen?" (P2, Workshop 1)
>
> "Is the name of the game to make our best guesses of what we think will happen?" (P3, Workshop 2)

These questions did not signal disengagement but an active process of grappling with the speculative frame as participants calibrated their mental models of the exercise. Through discussion and facilitation, they gradually moved from "forecasting" toward more creative and agentic worldbuilding.

By the diorama-building stage, participants were not only engaging with the materials but co-authoring complex relational futures. This shift was especially visible in their use of the string to trace political, technological, and bodily connections, surfacing entanglements that might otherwise have remained abstract.

Tensions Between Pessimism and Possibility

Discussions frequently revealed tensions between dystopian expectations and desires for more hopeful futures. Cultural exposure to apocalyptic narratives in media emerged as a recurring influence:

> “I really don't know how to speculate because just seeing so many dystopian movies.” (P3, Workshop 2)
>
> “I think commonly, what we all do is think that the world is definitely going to become worse… we don't always have to be pessimistic.” (P5, Interview)

Yet these same conversations often led to reframing. Participants began to differentiate between what is probable and what is preferable, emphasizing speculative design’s capacity to open imaginative agency:

> “Thinking about things in a light of what's possible versus what's probable, and what's preferable.” (P2, Workshop 2)

This mental shift was expressed not just conceptually but materially as participants rearranged elements, proposed new F/Actors, and debated alternative outcomes, producing hybrid visions of resilience and disruption.

Collaboration as a Catalyst

The collaborative nature of the workshop surfaced the generative value of diverse perspectives. Participants frequently noted how others introduced new framings or surfaced overlooked issues:

> “When there's more people working on something together, you're gonna be able to create ideas that people couldn't create on their own.” (P4, Interview)
>
> “I definitely learned about the varying interest... Being in this collaborative environment made me consider a different perspective—one that I realized is obviously important.” (P2, Interview)

These differences did not always resolve into consensus, but instead created layered engagements reflecting the entangled realities of climate futures. For many, the ability to find common ground amid disagreement was itself a source of hope:

> “It was interesting to hear different outlooks and thoughts. And for us to also mutually agree on the same things honestly gave me hope.” (P7, Interview)

Situated Engagement and Emotional Resonance

Participants frequently grounded their speculative work in personal, lived, and local experience. Mapping Seattle, referencing regional species like mushrooms, or connecting weather events to refugee movement offered affective and spatial anchors for envisioning futures:

> “To talk about those in the workshop and make a map of Seattle, and here's where I live right now is like, really fun.” (P2, Interview)
>
> “Mushrooms are a constant of the world.” (P3, Workshop 2)

These moments reveal that engagement was not only cognitive or dialogic, but emotional and ecological, anchored in place, memory, and embodied intuition.

Shifting Framing and Evaluation Across Lab–Field–Showroom

Evaluation of *Speculative F/Actors* unfolded through shifting lenses aligned with the Lab, Field, and Showroom environments, each generating distinct forms of insight. In the Lab, evaluation focused on testing the clarity of prompts, pacing, and facilitation structures to understand how different configurations supported speculative engagement. The Field expanded this evaluation into lived and situated contexts, observing how participants' local knowledge and collective dialogue transformed speculative materials into relational and affective worldbuilding. In the Showroom, evaluation became dialogic and interpretive as public exhibition and audience feedback revealed how the artifacts provoked new conversations about agency, ecological entanglement, and climate ethics beyond the original participant group. Across these settings, evaluation shifted from measuring the success of a designed activity to tracing how speculation itself acted as an evaluative process that reflected ongoing negotiation between design intention, participant meaning-making, and the emergent ethics of collaborative imagination.

Tensions and Unexpected Dynamics

Across workshop iterations, several tensions and unexpected dynamics emerged that reshaped both the design and facilitation of *Speculative F/Actors*. One recurring tension involved a balance between structure and openness. While the five-step format helped participants situate within a speculative frame, too much structure risked constraining imagination, whereas too little led to unhelpful uncertainty and hesitation. Another tension arose between individual expression and collective authorship, as participants negotiated how to merge differing perspectives, values, and emotional responses into a shared vision of the future. Unexpectedly, affective moments such as laughter, disagreement, or silence often signaled points of deep engagement rather than disengagement, revealing speculation as a socially and emotionally charged process. These dynamics highlighted the fragile yet generative nature of collaborative speculation, where friction, ambiguity, and misalignment became opportunities for reflection on how entangled futures are co-constructed through dialogue, materiality, and care.

Step 4: Reflect and Disseminate

Throughout the development and facilitation of the *Speculative F/Actors: Climate Futures* workshop, I adopted a reflexive orientation that recognized the dynamic, co-constitutive relationship between the workshop, its participants, and myself as a researcher-designer-

facilitator. This reflexivity unfolded both in the design of the workshop tools and structure, and in the live, situated practices of facilitation during each session.

My role as facilitator changed across iterations as I experimented with different ways of supporting collaborative engagement. Early sessions involved more structured pacing and framing as I explored how to guide participants through speculative uncertainty and hold space for unfamiliar forms of participation. Over time, I found that a lighter facilitation style that emphasized participant-led interpretation and emergent conversation often created more space for collective meaning-making. Prompts became more open-ended, theoretical framing was introduced dialogically, and speculative space was actively protected from premature closure or pressures to resolve. This reflexive process became a way of attuning to what each workshop and group needed in order to engage in speculative collaboration.

Facilitation emphasized:

- Encouraging openness to uncertainty
- Supporting multiple perspectives
- Navigating moments of tension or discomfort
- Affirming the validity of emotional or affective responses

This shift toward a more distributed and collaborative facilitation model reflected the workshop's core commitments to entanglement, staying with the trouble, and co-construction.

Navigating the Tensions of Structure and Openness

One of the most persistent design tensions involved balancing the structured, scaffolded format with the openness needed for speculative thinking. Early pilot sessions revealed that highly structured narrative prompts or overly abstract theory presentations limited participant engagement and constrained the imagination. In response, I made several design and facilitation pivots:

- Replacing theoretical slides with intuitive, materially grounded prompts (e.g., "vibe cards" instead of test tubes)
- Reducing the number of required tasks and emphasizing participant choice and agency
- Shifting from linear narratives to relational mapping using string and spatial composition

These changes were informed not only by participant feedback, but by my own observations of where engagement was being interrupted or constrained. Moments of friction often served as productive sites of reflection and redesign.

Iteration as Reflective Practice

Each iteration of the workshop represented a technical adjustment and a reflective pivot:

- From Pilot 1 to Workshop 1: shifting from dense theory to tactile engagement
- From Workshop 1 to Pilot 2: reducing cognitive load and emphasizing participant agency
- From Pilot 2 to Workshop 2: localizing content and embracing diverse participant epistemologies

Designing with Uncertainty

A final thread of reflexivity involved embracing uncertainty as an ethical and methodological commitment and a legitimate and necessary component of both design and facilitation. Building on the speculative provocations of *Post(-)human Hazmat*, *Speculative F/Actors* reframed uncertainty not as a barrier to be overcome, but as a shared condition of inquiry to be held. Whereas *Post(-)human Hazmat* was designed to support individuals in developing a single narrative thread as an introspective practice. In contrast, Speculative F/Actors invited multiple, sometimes conflicting stories to emerge in parallel through collective worldbuilding. As a facilitator, this shift toward collaborative storytelling required a deeper commitment to ambiguity: not only holding space for unresolved ideas, but actively designing for friction, divergence, and partial perspectives. Across workshops, this became less a methodological preference and more an ethical necessity, acknowledging that climate futures are not only nonlinear and entangled, but necessarily co-authored.

Dissemination and Audience Response

Dissemination of the *Speculative F/Actors* work took multiple forms, bridging public engagement and academic contribution. The workshop culminated in a gallery installation as the Featured 2023 STEAM Artist in Residence (total exhibition visitation: 7,365) at the Pensacola Museum of Art (MoA), where the dioramas, relational string maps, and workshop documentation were presented as part of an exhibition on speculative environmental futures. Figures 5.9 and 5.10 (below) show how the workshop materials were displayed, inviting museum visitors to engage directly with the speculative artifacts and reflect on their own entangled relationships with climate and place.

Figure 5.9. *Speculative F/Actors in STEAM exhibition at Pensacola Museum of Art (MoA).*

Figure 5.10. *Speculative F/Actors in STEAM exhibition at Pensacola Museum of Art (MoA).*

Figure 5.11 (below) shows the projected wall text introducing the STEAM exhibition at the Pensacola Museum of Art. The text projection displayed two paragraphs that acknowledged featured artists and contributors, and described that "the main focus of the exhibition centers around the idea of ecosystems as a metaphor for critical thought."

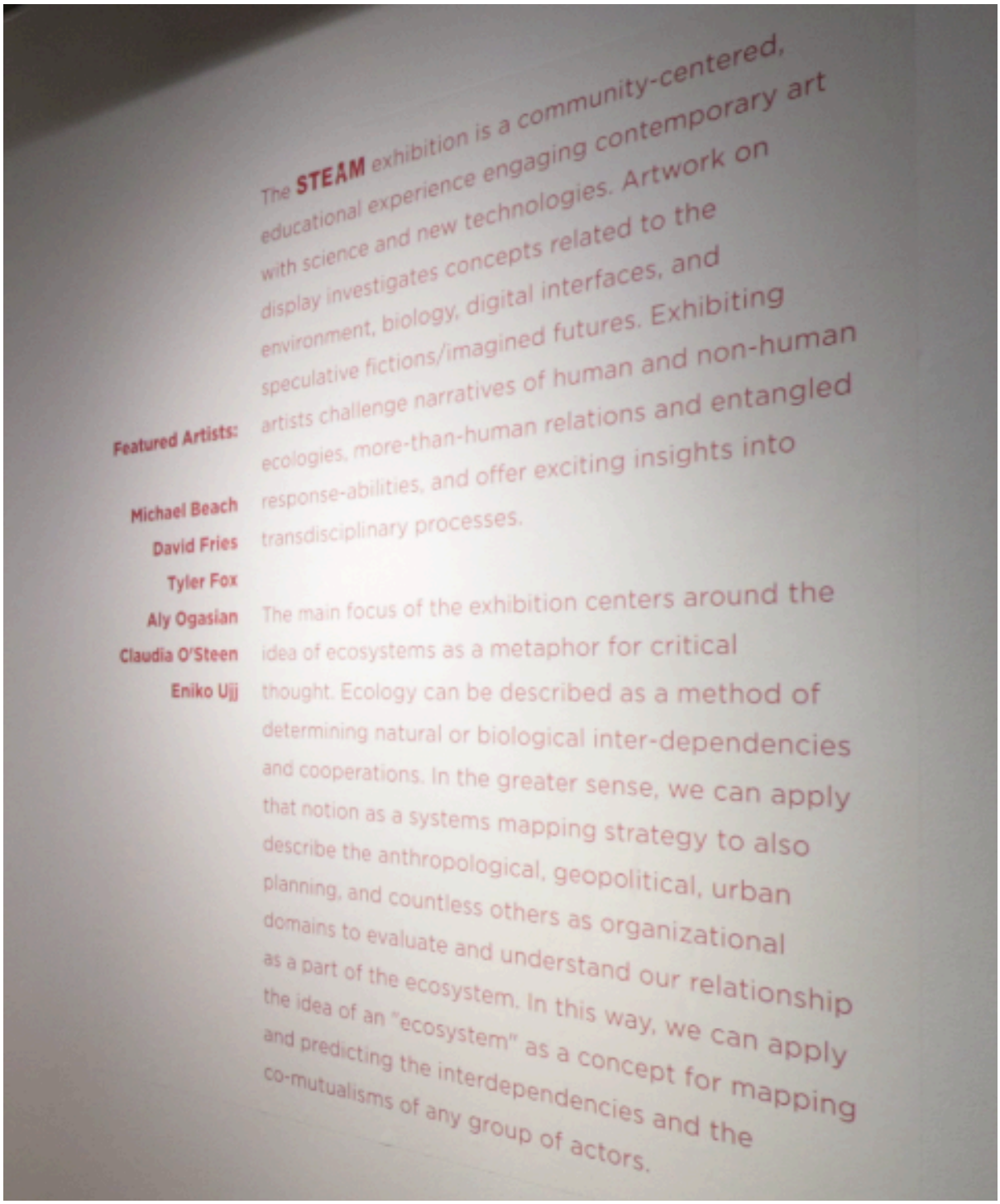


Figure 5.11. *Projected wall text introducing the STEAM exhibition and featured artists.*

Beyond the museum setting, the research was also disseminated through a pictorial presented at the Halfway to the Future 2024 Symposium (October 21–23, Santa Cruz, CA).[173] This publication presented the workshop's methodological innovations, framing collaborative speculation as a means of cultivating entangled ethics within design research. Together, these dissemination pathways extended the work from participatory experiment to public provocation, inviting audiences to imagine, reflect, and build upon the relational futures explored through *Speculative F/Actors*.

Step 5: Repeat

The *Speculative F/Actors* investigation revealed that student participant knowledge is often broad and experiential rather than specialized. It raised questions about how outcomes are shaped by those who are participating and how speculative design might engage more directly with the technical and systemic dimensions of wicked problems. Moving forward, I became interested in how to further ground speculative collaboration at specific junctures where complex challenges such as the climate migration, marine energy, and the circular economy intersect.

These insights shaped the design of the next investigation, *Entangled Justice*, which extends the speculative inquiry into contexts where participants are already working to address wicked problems in practice. Rather than inviting participants solely for their openness to speculation, this next phase intentionally engages domain experts, practitioners, and researchers whose everyday work navigates the entanglements of policy, infrastructure, ecology, and justice. This shift explores how *designing for entangled speculation* might operate as a reflective or imaginative exercise and a collaborative tool for rethinking real-world systems and relationships.

The next investigation serves as a method for deepening and contextualizing the framework, allowing speculative design to move closer to the sites of action where environmental and sociotechnical transformations are already unfolding. Each iteration continues to refine how speculation functions as a way of knowing and intervening, grounded in relational practices and responsive to the complexities of the worlds we inhabit and co-create.

[173] Beach, Michael W., Christina Graves, and Tyler Fox. (2024). "Speculative F/Actors: Climate Futures – Crafting a Workshop for Collaborative Worldbuilding in Cataclysmic Climates." In Halfway to the Future. ACM.

Chapter 6: Investigation 3 - Entangled Justice

> "An orientation to configuration reminds us to reanimate the figures that populate our socio-material imaginaries and practices, to examine the relations that they hold in place and the labours that sustain them, and to articulate the material semiotic reconfigurations required for their transformation."
> – Lucy Suchman , Configuration (Inventive Methods, p. 58)[174]

> "Consider the explanations that come to mind to explain (even defensively) why you do not know these things. These stories about unimportance, difficulty, obscurity, inefficiency (too little time or bang for the buck), and exhaustion speak to the ways in which your knowledge and attention and caring have been shaped. Are there also counterstories about this ignorance, accounts of others who know and care so you do not have to?"
> - (Dumit, 2014, p. 356)[175]

Up to this point in my research, I approached entanglement as a way of understanding relationality as I had found it described in HCI, anthropology, the social sciences, and the humanities. In these fields, each discipline offers its own way of describing how humans, technologies, societies, and environments are entangled through ongoing relations. They offer vocabularies for thinking about interdependence, situated knowledge, and ethical responsibility within complex systems. However, I found, *entanglement* was rarely defined explicitly or clearly, and often conflated with relationality. It was toward the end of this investigation that my understanding of entanglement began to shift toward quantum interpretations, where *entanglement* is described as a physical condition of inseparability, nonlinearity, and nonlocality. This connection between relational and quantum conceptions of entanglement opened new possibilities for thinking about design, ethics,

[174] Suchman, Lucy. "Configuration." In *Inventive methods*, pp. 48-60. Routledge, 2012.
[175] Dumit, Joseph. 2014. "Writing the Implosion: Teaching the World One Thing at a Time." *Cultural Anthropology* 29 (2): 344–362.

and justice. I discuss this development and its implications for the *Designing for Entangled Speculation* framework in Chapter 7.

Step 1: Select

The *Entangled Justice* investigation builds upon insights from the previous investigations: *Post(-)human Hazmat* and *Speculative F/Actors,* which explored multispecies care, collaborative speculation, and staying with the trouble of entangled dynamics of wicked problems. This investigation provided a reconfiguration for designing for entangled speculation examining how design might engage with entangled complexities of justice, knowledge, and technology.

The *Speculative F/Actors* investigation showed that while participants could collaboratively imagine future scenarios, they struggled to sustain shared understanding across disciplinary, epistemic, and affective differences. Participants navigated uncertainty, disagreement, and emotional resonance as they co-constructed climate futures, revealing that speculation is not a neutral or frictionless act, but one charged with power, history, and relational complexity. These dynamics raised a deeper research problem: how might design research facilitate collaborative imagination while attending to the uneven politics of participation, knowledge, and justice within these entanglements?

The findings also revealed limitations of generalized expertise. While participants often brought valuable perspectives, their knowledge was often broad rather than deeply grounded in specific systems or contexts. For *Entangled Justice*, I sought to bring together a diverse group of participants who each held deep, situated expertise related to a shared wicked problem. This shift in focus aimed to explore how entangled speculation could operate within domains of professional, scientific, and community practice where participants already contend with the real complexities, constraints, and ethical stakes of their work. This investigation treats design as a way to reveal and reconfigure visions of the future, inequities, exclusions, and accountabilities embedded within these relations.

Why was this particular site, theme, and provocation chosen?

For the *Entangled Justice* investigation, I wanted to design a workshop that brought together researchers, practitioners, and activists whose work intersects around a shared focus on a wicked problem. The goal was to create a space where participants could examine the entangled knots and imaginaries that shape their work and explore the multiple dimensions that connect past, present, and future possibilities within their respective domains. Across discussions and collaborative activities, the workshop provided scaffolding

for broader conversations about how participants might learn from collaborative reframing and reflection.

The conceptual grounding for *Entangled Justice* draws on Haraway's notion of staying with the trouble (2016) and Joseph Dumit's Writing the Implosion (2014), each offering a mode of inquiry attentive to how knowledge is situated, partial, and co-constituted. Where previous investigations emphasized speculative imagination, this study engages with speculative reflection through multiple dimensions of justice asking how speculative methods can foreground gaps, contradictions, and asymmetries in how entanglements are known, represented, and governed.

How does this investigation continue the RtD cycle?

This investigation begins a new cycle of Research through Design (RtD) built directly on the reflective insights and methodological shifts developed through *Speculative F/Actors*. *Entangled Justice* starts from existing entanglements in practice and uses design to reveal their ethical and epistemic dimensions. As the first two investigations did, this investigation embraces ambiguity, invites partial perspectives, and designs for friction rather than resolution. Through these commitments, *Entangled Justice* establishes a new phase of RtD inquiry.

This investigation considers how methods for engaging with entanglement can open new possibilities for practicing design justice. By tracing interdependencies and acknowledging the partial and situated nature of knowledge, *Entangled Justice* approaches design as a practice of relational accountability. Working within real-world systems such as climate migration, marine energy, and the circular economy foregrounds the ethical tensions and responsibilities that shape collaborative inquiry. These engagements raise ongoing questions that guide the next phase of this research: How can methods of entanglement foster more ethical and relational approaches to design justice? What does it mean to design with experts and practitioners whose work already confronts wicked problems such as climate migration, marine energy, and the circular economy?

Step 2: Design

The design of the *Entangled Justice* investigation developed through an iterative process that brought together insights from several interconnected projects. This section outlines the literature and prior work that informed the design, as well as the field and studio explorations that shaped it: the "Entanglement Methods" DRG (Autumn 2022), which introduced mapping as both a methodological and ethical practice, the *Politics of Imaginaries* workshop (DIS 2023), which explored humanistic inquiry in HCI, and the *Diffraction*

Workshop, (early name for the *Entangled Justice* workshop) a pilot held with an interdisciplinary community of researchers and engineers at the Pacific Marine Energy Center (PMEC). The following sections describe how these formative efforts shaped the structure and format of the *Entangled Justice* workshop.

Literature and Prior Work Informing the Design

The design of this investigation builds upon a lineage of thought in Human–Computer Interaction (HCI) that has progressively expanded its scope of concern: from user-centered to human-centered and now toward more-than-human and entanglement-based design. Early user-centered paradigms focused on optimizing technologies for individual users. Human-centered design extended that focus to tertiary stakeholders and societal impacts, prompting critical questions about surveillance capitalism, erosion of privacy, and destabilization of democratic systems. Scholars in this space began to ask: Who is left out, and what are the consequences of design decisions? What ethics underlie our designs? Building on this trajectory, more-than-human and entanglement approaches extend ethical attention to non-human species, temporalities, and ecologies.

The work of Donna Haraway (2016)[176] and Karen Barad (2007)[177] reframes design as relational and performative, emphasizing that meaning and matter emerge through intra-action. Christopher Frauenberger's Entanglement HCI (2019)[178] advances this orientation through four lenses: (a) the performative relationships between humans and technology, (b) knowledge generation around phenomena rather than subjects or objects, (c) tracing accountabilities and ethical encounters, and (d) developing practices of design and mattering that move beyond user-centered logic. The *Entangled Justice* workshop draws conceptually from these sources as well as Joseph Dumit's "Writing the Implosion," which provides a method for mapping relations through multiple dimensions while acknowledging the gaps and absences within any system of knowledge. Dumit's "Writing the Implosion" activities were inspired by an inquiry around tracing connections posited by Donna Haraway. "Any interesting being in technoscience, like a textbook, molecule, equation, mouse, pipette, bomb, fungus, technician, agitator, or scientist can—and often should—be teased open to show the sticky economic, technical, political, organic, historical, mythic, and textual threads that make up its tissues."[179] As Dumit observes, the activity is equally to make evident the gaps in your knowledge, and "to imagine how and where you could get the answers you are missing."[180] The mapping process becomes a diffractive act of

[176] Haraway, Donna J. 2016. Staying with the Trouble: Making Kin in the Chthulucene. Duke University Press.
[177] Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press, 2007.
[178]Frauenberger, Christopher. 2019. Entanglement HCI: The Next Wave?. ACM Transactions on Computer-Human Interaction (TOCHI) 27, 1 (2019), 1-27.
[179] (Donna Haraway 1997, p. 68)
[180] (Dumit, 2014, p. 356)

inquiry: a way to stay with the trouble by tracing the ethical and political effects of relationships as they unfold.

Fieldwork and Studio Exploration

There are three major explorations that inform the design of the *Entangled Justice* workshop:

1. The "Entanglement Methods" DRG AU22.
2. The *Politics of Imaginaries* workshop DIS23.
3. The *Diffraction Workshop,* a pilot workshop held at the PMEC conference.

I walk through these three explorations below and describe how they each contribute to the development of the final *Entangled Justice* workshop.

Entanglement Methods DRG (September - December 2022)

The Entanglement Methods DRG, titled "Entanglement Methods: Mapping Ethical Relations and Responsibilities in Community Science Program," served as the studio-based precursor and field site for this investigation. The DRG met for 2 hours once a week for ten weeks over Zoom. I designed and facilitated this DRG with advising support from Assistant Teaching Professor Kristin Dew. The DRG brought together eight undergraduate and graduate students to explore entanglement theory through readings, discussion, and collaboration with Forest Health Watch (FHW), a community science program that monitors the decline of the western redcedar (Thuja plicata) in the Pacific Northwest and conducts research on migration assistance, testing western redcedar lineages from warmer parts of Oregon in Seattle area locations. The partnership grounded the theoretical inquiry in a living ecological context, enabling participants to connect abstract discussions of entanglement to material practices of environmental observation and migration.

Over the ten-week quarter, the "Entanglement Methods" DRG explored entanglement as both a theoretical concept and a design methodology through readings and discussion. We began by grounding our understanding in Christopher Frauenberger's (2019)[181] "Entanglement HCI: The Next Wave?," identifying how entanglement theory reframes design around performative relations and accountability. Frauenberger's Entanglement HCI explores the following four perspectives: "(a) the performative relationship between humans and technology; (b) the re-framing of knowledge generation processes around phenomena; (c) the tracing of accountabilities, responsibilities and ethical encounters; and (d) the practices of design and mattering that move beyond user-centered design"

[181]Frauenberger, Christopher. 2019. Entanglement HCI: The Next Wave?. ACM Transactions on Computer-Human Interaction (TOCHI) 27, 1 (2019), 1-27.

(Frauenberger, 2019).[182] Subsequent sessions expanded this foundation through readings from Ezio Manzini on “Making Things Visible and Tangible,”[183] Donna Haraway's "Staying with the Trouble,”[184] and Joseph Dumit’s “Writing the Implosion,”[185] which informed early knowledge-mapping and visual design exercises. We integrated Lori Gruen’s concept of Entangled Empathy to consider ethical responsibility and care across species and systems, followed by exploration of Feral Atlas,[186] which modeled storytelling and mapping as relational research practices. Midway through the quarter, students prototyped design artifacts that translated these theoretical insights into experimental methods for mapping entanglement, receiving iterative feedback through group critique. The DRG culminated in a public showcase that presented emerging prototypes of entanglement maps and prompted feedback on how these mappings could reveal more-than-human relations and ethical responsibilities within environmental monitoring.

To ground our understanding of entanglements and to design methods for mapping entanglements, we partnered with a local community science program, Forest Health Watch (FHW). FHW collects data about declining western redcedar, a critical organism in Pacific Northwest (PNW) forests that is highly vulnerable to changes in climate. Why FHW as a partner? The Western Redcedar (WRC) is a tree species in the Pacific Northwest that is entangled in a network of cultural, historical, economic, and social importance. They provide a wide range of habitat for many species in the forest and can be directly linked to biodiversity. They are harvested in the timber industry, and have ties to many local economies. However, the WRC is a sensitive species to changes in the environment including changes in climate. Because of this sensitivity, some have proposed placing WRC around ports to act as early indicators of potential hazards, which raises ethical questions about more-than-human relations and the subjectification to harm and vulnerability. Our work focuses on making these stories of entanglement more visible with the goal to create design methods for mapping ethical tensions in other areas or design.

FHW Director, Joey Hulbert was generous with his time and support of the DRG, making time to meet with our research team a few times over the quarter. As the DRG team learned about the FHW mission and ongoing research, we used FHW as a grounding example to think through our readings and prototyping efforts: What relations are being designed or maintained through community science? What are the more-than-human relations being created? How are entanglements mapped in the current practices and what remains invisible?

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[182] Frauenberger, Christopher. 2019. Entanglement HCI: The Next Wave?. ACM Transactions on Computer-Human Interaction (TOCHI) 27, 1 (2019), 1-27.
[183]Manzini, Ezio. *Design, when everybody designs: An introduction to design for social innovation*. MIT press, 2015.
[184]Haraway, Donna J. Staying with the trouble: Making kin in the Chthulucene. Duke University Press, 2020.
[185]Dumit J (2014) Writing the Implosion: Teaching the World One Thing at a Time. Cultural Anthropology 29: 344–362.
[186] Anna L. Tsing et al., *Feral Atlas: The More-than-Human Anthropocene* (Stanford University Press, 2020).

The research group produced visual design artifacts, preliminary mapping exercises, and collective memos that examined the ethical dimensions of data collection and interpretation. In the final few weeks of the DRG, the research team generated visual design artifacts and developed key questions about values, methods, and responsibilities to inform future empirical work. The emerging research program positions entanglement mapping as both a design method and ethical practice, forming the foundation for subsequent investigations into emergence, design response, and situated ethics.

The Entanglement Methods DRG research team identified the following insights:

- **Mapping as Entangled Process**: Mapping is not a neutral representation but an active part of the entanglements it depicts, shaping what becomes visible and what remains unseen.
- **Community Science as Entanglement**: Working with FHW revealed that community science already performs entanglement by linking human, ecological, and technological systems through observation and care.
- **Ethics and Accountability**: Applying Haraway, Barad, and Frauenberger encouraged the research team to see design as a practice for cultivating ethical responsiveness rather than producing isolated artifacts.
- **Three Strands for Inquiry**: The DRG identified three potential focal areas of future research for studying relational and temporal complexity: Mapping Entanglements, Mapping Emergence, and Designing for Responsibility.

These insights directly informed the design of the *Entangled Justice* workshop, especially its emphasis on mapping entanglements as a collective and reflective act. This is where I started to explore concepts from quantum entanglement as an opening to think about diffraction. In this DRG, we explored concepts from entanglement theories through readings, discussions, with the goal of developing entanglement methods and practices of design and mattering that move beyond user-centered design that help trace accountabilities, responsibilities, and ethical encounters.

Politics of imaginaries[187] DRG SU23 & DIS23

The Politics of Imaginaries workshop, held at the Designing Interactive Systems (DIS) Conference in 2023, explored how humanistic inquiry can expand the ethical and political imagination of HCI. The workshop brought together scholars and practitioners across design and the humanities to examine the technopolitical imaginaries that shape how technologies are conceived, developed, and governed. Drawing on critical traditions in

[187] Gabrielle Benabdallah, Michael W. Beach, Lucy Suchman, Kavita Philip, Nathanael Elias Mengist, and Daniela Rosner. (2023). "The Politics of Imaginaries: Probing Humanistic Inquiry in HCI." *Designing Interactive Systems* (DIS), Carnegie Mellon University, Pittsburgh, Pennsylvania.

feminist STS, design justice, postcolonial computing, and decolonial studies, the workshop asked how speculative and critical design practices might move beyond abstract ethics toward more historically situated and politically accountable forms of imagination. This was a first attempt to mobilize and modify Joseph Dumit's "Writing the Implosion" activity to support participants in developing knowledge and ignorance maps, and tracing the visible and invisible dimensions (e.g., labor, material, political, historical, and symbolic) that underpin sociotechnical systems. Figure 6.1., (below) shows a zoomed out screenshot of the collaborative Miro board used by participants during the workshop to explore each other's knowledge maps. Participant discussions explored the question: How might we consider the challenge of measuring and proving such experiences and the limitations of quantification?

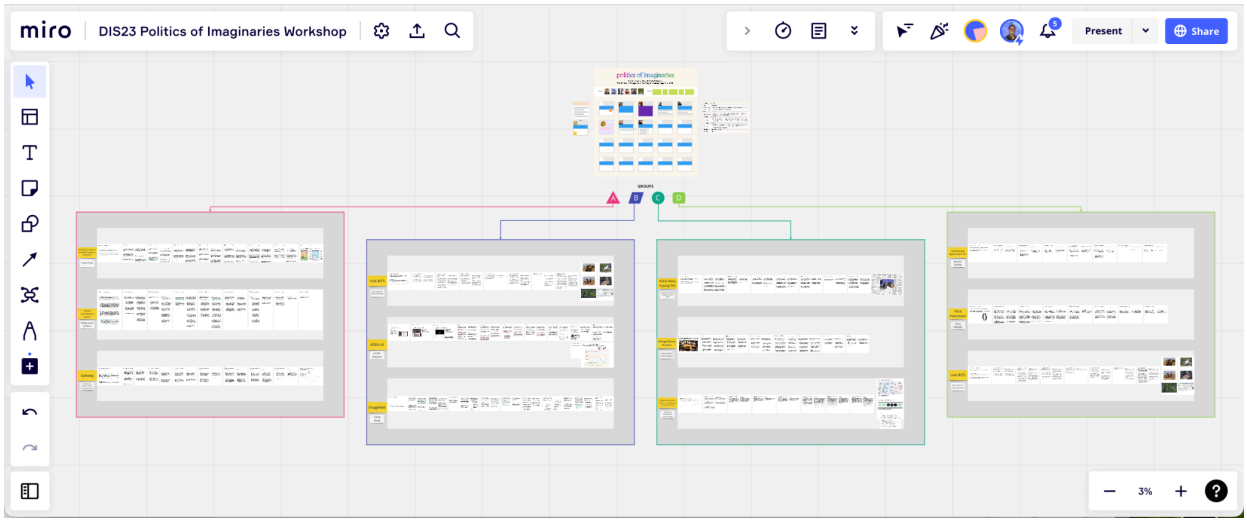

Figure 6.1. *Politics of Imagination Miro board showing 12 knowledge maps created by workshop participants, organized into four groups of three. Intentionally zoomed out to redact content.*

The concerns that emerged in this workshop directly informed the development of the *Entangled Justice* investigation. Discussions around accountability, partial knowledge, and the limits of datafication highlighted the need for methods that embrace the unknown as an active and ethical space of inquiry. In the reflective discussion, the participants explore the positive agency of not knowing and embrace the notion that ignorance is not merely an absence but an active part of the research object. They acknowledge the partiality of knowledge and the blind spots in their understanding. The recognition that imaginaries carry both creative and political force guided the move toward diffractive mapping as a design method, where participants trace relations and tensions rather than resolve them. These insights helped shape the *Entangled Justice* workshop's emphasis on collective reflection, ethical entanglement, and situated expertise as ways of exploring how design can engage with the politics of knowledge, care, and justice.

Diffractive Workshop Pilot (PMEC conference, Seattle; September 2023)

The exploration of quantum entanglement in this phase of the research opened a new line of inquiry into *diffraction* both as a physical phenomenon of complex relations studied in classical and quantum physics and as a conceptual tool for design. In quantum physics, diffraction describes the interference patterns that emerge when waves overlap, revealing relationships that cannot be understood from any single perspective. This idea resonated with my growing interest in entanglement as a method for triangulation, a way to approach complex or uncertain situations by tracing the differences, overlaps, and interferences among multiple forms of knowing. Translating these concepts into design practice suggested that diffraction could serve as a technique for understanding how relations produce meaning, how knowledge is shaped by position and context, and how designers might engage those patterns to surface new ethical and relational insights.

As the next iteration in developing entanglement-based design methods, I designed and piloted the *Diffraction Workshop: Trace Mattering and Meaning for Response-ability"* at the Pacific Marine Energy Center (PMEC) Conference in September 2023. The PMEC conference brought together researchers and engineers working at the intersection of marine energy, ocean ecology, and community engagement. This was an ideal context for testing how speculative and relational methods might operate within highly technical domains that already grapple with environmental and ethical complexity.

The workshop introduced participants to entanglement and diffraction as conceptual and methodological tools for addressing wicked problems. Mobilizing Joseph Dumit's "Writing the Implosion" activity for a second time, participants developed knowledge maps of their work across 14 dimensions including labor, material, political, historical, ecological, and symbolic among others. Working in small groups, they engaged in three activities: (1) descriptive mapping, where participants identified what was known and what remained uncertain; (2) generative mapping, where they collaboratively expanded on each other's maps by engaging with gaps and absences; and (3) a diffractive reflection, where they compared their maps and traced how differences across perspectives revealed underlying assumptions, disciplinary boundaries, and ethical tensions.

Through these activities, participants recognized that many of their technical and ecological challenges were also epistemic and relational, shaped by the boundaries of their own research practices. Several participants reflected that the process helped them "see their work differently" and identify new questions about collaboration, measurement, and ecological responsibility. This pilot demonstrated that diffractive mapping could foster critical reflection even within data-driven and engineering-focused environments. The workshop's success confirmed the value of inviting domain experts into speculative and entanglement-based design practices and directly informed the structure of the *Entangled*

Justice workshop, where these methods were expanded into longer, multi-stakeholder engagements centered on justice, accountability, and situated expertise.

Lab-Field-Showroom Environment

Across its iterations, *Entangled Justice* engaged each mode of Koskinen et al.'s (2011) Lab–Field–Showroom framework to iteratively test and reframe its speculative design inquiry. The lab work for this investigation consisted primarily of assembling and iteratively refining two interlocking scaffolds: the 14-dimensions for knowledge maps as they are found in "Writing the Implosion" (Dumit, 2014) (see Appendix 6.1), and the glossary of 21 justice terms as they are found in *The Promise of Multispecies Justice* (Chao, Bolender, and Kirksey, 2022),[188] (see Appendix 6.2). Drawing on energy and climate justice scholarship, STS, Indigenous and decolonial theory, and the design methods developed in the earlier chapters, I treated these diagrams as prototypes that could hold together many kinds of entanglement at once while still remaining operable in a two-hour workshop. In this sense, the lab here is less about making new artifacts in a studio and more about constructing shared conceptual "apparatuses" that can travel into other spaces.

The field in this investigation is not a single geographic site but a set of ongoing, high-stakes projects that participants brought with them into the virtual room: marine renewable energy deployments on specific coastlines, regional tool-library networks, climate-assisted tree migration projects, and urban forest resilience work. Even though the workshops were hosted on Zoom and Miro rather than in a community center or shoreline town, the conversations were saturated with situated struggles such as regulatory processes, grant structures, local resistance, Indigenous sovereignty, and multispecies impacts. Following the arc of the previous investigations, I treat these workshops as field encounters because they required me to step into existing socio-technical worlds and to co-think with people whose accountability is to communities, ecosystems, and agencies beyond the university.

Finally, the showroom for *Entangled Justice* is comparatively modest and mostly diagrammatic, but still important. The primary staging device is the Miro board itself: a shared, temporally bounded surface on which the 14 dimensions, glossary of 21 justice terms, and participants' sticky notes and drawn connections accumulate in real time. Rather than the highly produced installations of *Post(-)human Hazmat* or the tactile kit of *Speculative F/Actors*, the spectacle here is the visible thickening of the map as people write, cluster, and re-frame each other's contributions. The board persists after the workshops as a set of layered knowledge maps that can be re-entered as research data and as future prompts. In designing the investigation, I understood these boards (and eventually this

[188] Chao, Sophie, Karin Bolender, and Eben Kirksey. 2022. "Introduction: Who Benefits from Multispecies Justice?" *The Promise of Multispecies Justice*. Duke University Press. (3).

chapter, future publications, and a "designing for entangled speculation" framework) as an emergent showroom: places where the conceptual apparatus and field encounters are curated for other audiences who were not in the Zoom room but are nonetheless implicated in the same entangled futures. See the blank Miro board template in Figure 6.3, high-level screenshots of the three boards in Figure 6.4, and larger screenshots of each board in Appendix 6.2. below.

Entangled Justice Workshop

The final iteration in this *Entangled Justice* investigation is the *Entangled Justice* workshop. Three instantiations of this final workshop were conducted, across three different focus areas: Climate Migration, Marine Energy, and Circular Economy. These areas were chosen based on their local proximity to the Seattle area, where I live and work, and their topical proximity to wicked problems. Each focus area reflects complex challenges that resist linear solutions and require situated, cross-sector collaboration. Climate migration represents the entangled social, political, and ecological forces that drive human and more-than-human displacement. Marine energy represents the tensions between technological innovation, environmental stewardship, and community values in the pursuit of sustainable futures. Circular economy foregrounds the systemic relationships among consumption, waste, and resource regeneration, inviting critical reflection on how design can reshape material and economic flows. Together, these areas situate the *Entangled Justice* workshop within a landscape of real and ongoing problem spaces, where questions of justice, accountability, and relational ethics must be imagined and practiced in collaboration.

Workshop Recruitment

Participants were recruited through professional and academic networks based on their connection to the focus area. Recruitment targeted individuals whose work engaged directly or indirectly with the topic, inviting a range of perspectives and levels of expertise. The invitation emphasized that the workshop welcomed participants from diverse professional backgrounds, including researchers, engineers, policymakers, designers, and practitioners working within or alongside these domains.

Recruitment materials were distributed through email lists and direct outreach, including PMEC's network coordinators, UW faculty and graduate research groups, and relevant community and technical organizations e.g., Forest Health Watch, NE Seattle Tool Library, Reuse Commons. Messaging included a link to a When2Meet scheduling poll to identify a shared two-hour window in November that accommodated all participants. Once a date and time were confirmed, participants received a calendar invitation including a Zoom link and an information sheet outlining the purpose of the study, the structure of the session, and participation terms.

The recruitment invitation framed the workshop as part of a broader series exploring entangled justice, where participants collaboratively engage in activities designed to probe and imagine the social and ecological implications of their work. Following the workshop, participants were invited to share reflections in a brief one-on-one interview, conducted either immediately after the session or online at a later time. In total, participation required no more than two hours.

All participants received study information and provided informed consent prior to participation. Consent forms outlined recording procedures, use of photographs and workshop materials, and voluntary participation terms. All workshops were held over Zoom. The study was approved under the University of Washington's IRB exempt status.

Workshop Structure and Format

The final *Entangled Justice* workshop structure began with introductions where participants shared their area of work and expertise, reflected on their relation to the shared focus (climate migration, marine energy, or circular economy), and participated in both group discussions and two key collaborative activities. The first was a descriptive mapping activity, which helped orient participants to each other's perspectives through the dimensions of the knowledge map. The second, a reflective activity, built on these discussions and encouraged deeper engagement with a chosen dimension as it related questions of injustice. Through these engagements, participants developed ignorance maps, visualizations of what remains unseen or unknowable within their work, and used these as prompts for group reflection.

Each workshop was held over Zoom using a shared Miro board where participants collaboratively generated a collective artifact that anchored the conversation. My intention was to foster an inclusive and speculative environment that approached relationships as a form of critical and generative inquiry. By envisioning plural futures that confront historical injustices, the workshop sought to open possibilities for more equitable and imaginative framings of the future, foregrounding justice not as an endpoint, but as an ongoing, entangled process of learning and making sense together.

Materials, Prompts, and Activities

To ground these engagements, I invited participants to develop a shared knowledge map using the Miro board based on a modified version of Joseph Dumit's (2014) "Writing the Implosion" activity. See a zoomed out screenshot of the Miro board template in Figure 6.2. (below) that includes labels to indicate each of the sections. The list of activities are highlighted in orange (see Table 6.1 for the full list of activities, below), the "Dimensions Wheel" highlighted in purple, and the "Glossary of Justices" highlighted in green.

Activities: This mapping exercise prompted participants to engage with the chosen focus area and articulate their knowledge through a set of relational dimensions, including: *Labor, Professional/Epistemological, Material, Technological, Context and Situatedness, Political, Economic, Textual, Bodily/Organic, Historical, Particle, Educational, Mythological, and Symbolic.* Table 6.1. (below) outlines the workshop activities with Climate Migration as the example. As seen in Figure 6.2, a blue arrow points to Part 1 of the Activities list. The arrow is moved downward throughout the workshop to indicate the current activity and preview what comes next. There is also a purple star icon at the bottom left corner of the Activities list. In Part 4, participants choose a single dimension to explore further in the second half of the workshop. The star is then placed beside the chosen dimension on the wheel of dimensions to track this decision.

Dimensions Wheel: This wheel presents the 14 dimensions, including descriptions and questions, outlined from Dumit's "Writing the Implosion,"[189] activity. See the full list of dimensions and their question prompts in Appendix 6.1, below. There is space under each dimension for participants to add sticky notes. At the center of the dimension wheel is an inner circle that includes space for a Topic Focus, a place to name the overarching theme of the workshop (e.g., climate migration, marine energy, or circular economy). It also includes a set of blank sticky notes each with a name label that participants will claim for themselves in Part 1 of the workshop activities. See Figure 6.3 for a closer look at this inner circle.

[189] Dumit J (2014) Writing the Implosion: Teaching the World One Thing at a Time. Cultural Anthropology 29: 344–362.

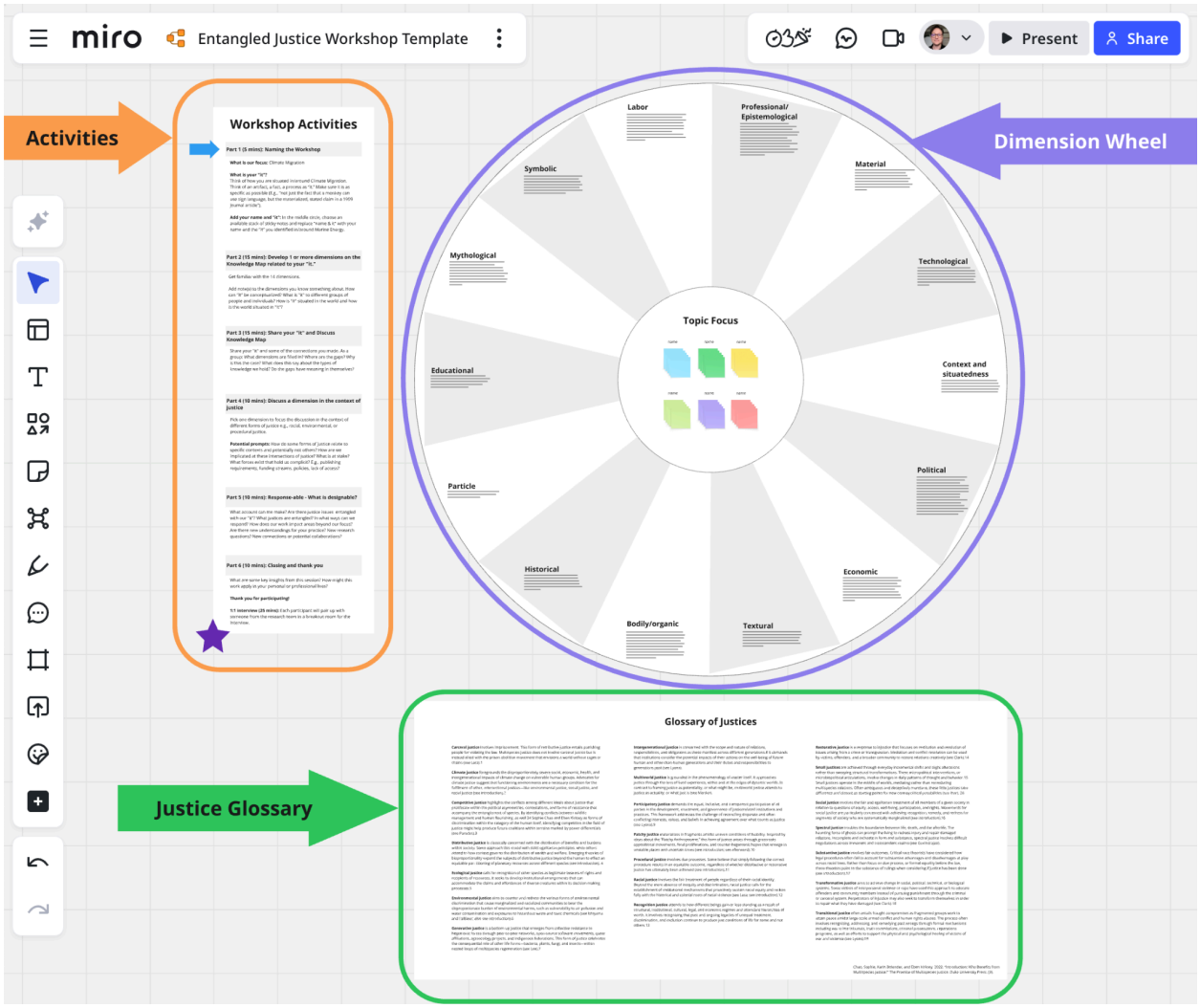

Figure 6.2. *Entangled Justice Workshop Template on Miro, labeled to show the layout of the board.*

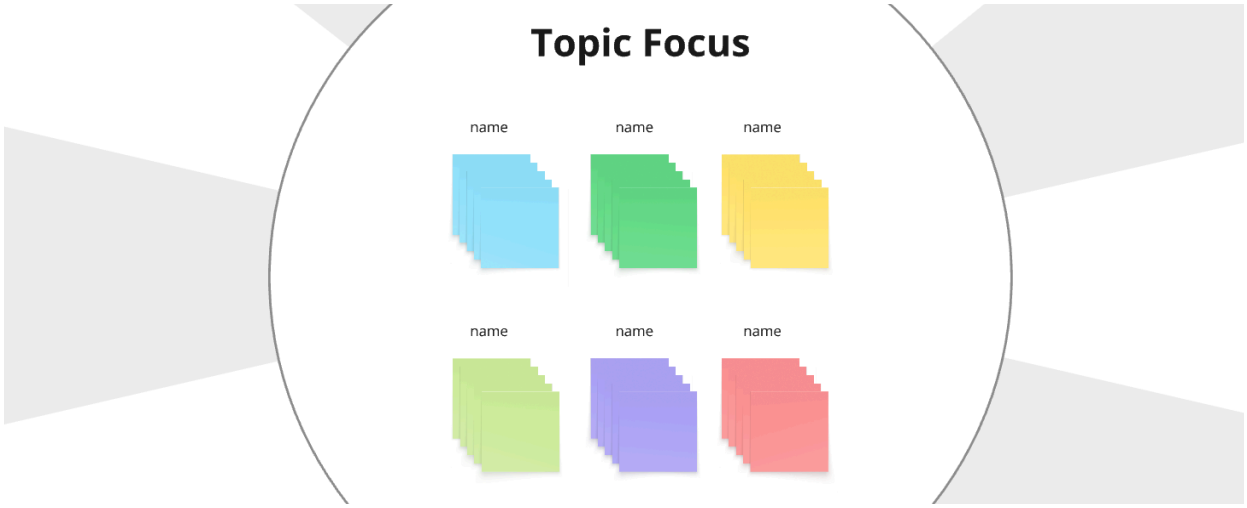

Figure 6.3. *Workshop Template: A closer look at the inner circle: topic focus, name labels, and blank sticky notes.*

Glossary of Justices: This section presents the 21 different framing of justice, as they are found in *The Promise of Multispecies Justice* (Chao, Bolender, and Kirksey, 2022).[190] This glossary is used in Part 4 of the workshop activities where participants are asked to discuss a chosen dimension in the context of different framings of justice. How do these different framings of justice change the framing of the chosen dimension? See the full list of justices in Appendix 6.2, below.

Table 6.1. *Workshop Activities for Entangled Justice workshop.*

Part 1 (5 mins): Naming the Workshop	**What is our focus:** Climate Migration **What is your "it"?** Think of how you are situated in/around Climate Migration. Think of an artifact, a fact, a process as "it." Make sure it is as specific as possible. **Add your name and "it":** In the middle circle, choose an available stack of sticky notes and replace "name & it" with your name and the "it" you identified in/around Climate Migration.
Part 2 (15 mins): Develop 1 or more	Get familiar with the 14 dimensions.

[190] Chao, Sophie, Karin Bolender, and Eben Kirksey. 2022. "Introduction: Who Benefits from Multispecies Justice?" *The Promise of Multispecies Justice*. Duke University Press. (3).

dimensions on the Knowledge Map related to your "it."	Add note(s) to the dimensions you know something about. How can "it" be conceptualized? What is "it" to different groups of people and individuals? How is "it" situated in the world and how is the world situated in "it"?
Part 3 (15 mins): Share your "it" and Discuss Knowledge Map	Share your "it" and some of the connections you made. As a group: What dimensions are filled in? Where are the gaps? Why is this the case? What does this say about the types of knowledge we hold? Do the gaps have meaning in themselves?
Part 4 (10 mins): Discuss a dimension in the context of justice	Pick one dimension to focus the discussion in the context of different forms of justice e.g., racial, environmental, or procedural justice. **Potential prompts:** How do some forms of justice relate to specific contexts and potentially not others? How are we implicated at these intersections of justice? What is at stake? What forces exist that hold us complicit? E.g., publishing requirements, funding streams, policies, lack of access?
Part 5 (10 mins): Response-able - What is designable?	What account can we make? Are there justice issues entangled with our "it"? What justices are entangled? In what ways can we respond? How does our work impact areas beyond our focus? Are there new understandings for your practice? New research questions? New connections or potential collaborations?
Part 6 (10 mins): Closing and thank you	What are some key insights from this session? How might this work apply in your personal or professional lives? **Thank you for participating!**
1:1 interview (25 mins)	Each participant will pair up with someone from the research team in a breakout room for the interview.

Step 3: Evaluate

Facilitation, Documentation, and Interpretation

Each workshop was audio- and video-recorded, and photographs were taken of the dioramas and string mappings. These materials were later reviewed to extract key themes, speculative moves, and relational framings. Post-workshop interviews, lasting approximately 30 minutes each, were transcribed and coded thematically, revealing shifts in participant understanding, engagement, and imaginative framing. See more about the research team and process in Chapter 3: Methods.

Each *Entangled Justice* workshop was audio-recorded, and all post-workshop participant interviews were also recorded for later analysis. Workshop recordings captured the flow of discussion, collaborative mapping activities, and moments of reflection that revealed how participants intersected their areas of expertise and shared knowledge with one another, sparking new meanings and connections. These materials were reviewed to identify key insights and shifts in collective understanding that emerged throughout the sessions. Interview transcripts were thematically coded to trace how participants interpreted the activities, rethought their assumptions, and articulated new connections between the dimensions, justices, and their work. See Chapter 3: Methods for details on the research team, facilitation approach, and analysis.

Artifacts, Outputs, and Interpretation

The primary artifacts produced through the *Entangled Justice* workshops were the collaborative Miro boards that captured participants' knowledge maps. See Figure 6.4 (below) a zoomed out view of the three populated dimension wheels, or knowledge maps. See larger versions of these knowledge maps in the Appendix 6.3, below. The resulting knowledge maps visualized the relationships among the 14 dimensions. This could be read as a heat map revealing the knowledge depth by each dimension while the gaps show the ignorance map, where there is less known. Because this was a collaborative map, it also revealed areas of shared understanding and gaps or tensions between perspectives.

The knowledge maps functioned as documentation output of the workshop that coincided with the workshop transcripts in later analysis, but more importantly, these artifacts functioned as speculative artifacts and cognitive tools that participants could refer to during their conversations in the workshop. As participants added, rearranged, and commented on sticky notes, the maps grew into layered visualizations that described the group's collective understanding.

Figure 6.4. *Dimension wheels populated with sticky notes from the three workshops.*

The primary outputs produced through the *Entangled Justice* workshops were the recorded conversations from the workshops and the post-workshop interviews. In the section below, I evaluate these outputs.

Workshop Overviews

In this section, I evaluate the outputs produced through the workshops and post-workshop interviews. I begin with a brief overview of each workshop, offering a high-level account of how each session unfolded and the key decisions made by each participant group. In the next section I present a set of insights that cut across all three workshops, highlighting patterns of resonance and shared meaning that emerged through the speculative engagements. Finally, I analyze the post-workshop interviews as a collective dataset, drawing out participants' reflections on the activities and the overall experience of the *Entangled Justice* workshops.

Workshop 1 Overview: Climate Migration

The *Entangled Justice: Climate Migration* workshop brought together participants working in ecology, restoration, and community science to explore climate-related movement across species through the shared knowledge map (see Appendix Figure 6.3.1). Although each person selected a specific "it," including frogs, water, trees, and climate smart plants, the conversation quickly moved beyond individual species to focus on water and habitat as the underlying conditions that shape survival and migration. As one participant reflected, while they initially centered frogs, "in reality the it, the material it, ends up being water," and that for amphibians "that water is like an extension of their body," which shifted the discussion toward rehabilitating habitats rather than only saving particular species. Another participant described long-lived trees as "witness[es] to change and without any control over it," linking trees, water, and animals in a multi-dimensional entanglement of bodily, historical, and ecological relations.

Participants also reflected on which beings receive attention and care, and which remain overlooked. One noted that some species "are not maybe as charismatic as western red cedar," while another observed that frogs are often seen as "unseen and gross and unimportant," in contrast to orcas, where "money's been put into studying orcas, you know, but not frogs." These comments highlighted how "charismatic species" attract funding, research, and policy focus, while less visible beings and their habitats are neglected. Throughout the conversation, participants sparked ideas off one another, drawing in references to Michelle Montgomery's work on plantation trees and ancestors' breath, "climate smart plants" and the question of "what should that future look like" in a radically altered Pacific Northwest, and new tools such as lidar and AI, building collective knowledge around climate change, multispecies ethics, and justice. A participant reflected that "with this new crisis, we also have new tools to observe our landscape and think about it," even as those tools raise new ethical tensions.

Highlighting one of the references drawn in the conversation, one participant describes Michelle Montgomery's work: "She talks about the trees on plantations and how to sequester carbon that's been exhaled by the slaves… thinking about the trees as conserving some of the body of those people." They then connect this to climate loss: "Climate change is killing these big old trees that have sequestered some of your ancestral… it's tragic, you know."

When the group moved to Part 4, they chose the *Bodily/Organic* dimension for deeper discussion on justice. This decision reflected the way bodies, breath, and water had come to organize the conversation, and it provided a lens for engaging the justice glossary. Participants made connections across dimensions such as carceral, recognition, and patchy justice to dams and water control, beaver-managed wetlands, agricultural livelihoods, and compensation for landowners. They also emphasized the need to "find out more information" about understudied species and to create conditions for "safe to fail" experimentation in ecological design. In this way, the workshop surfaced both the limits of current knowledge and the ethical stakes of deciding when to seek more data and when to act amid uncertainty.

Workshop 2 Overview: Marine Energy

The *Entangled Justice: Marine Energy* workshop brought together participants working on technology design, public engagement, and policy. In the knowledge mapping activities (see Appendix Figure 6.3.2), participants selected "it"s such as specific marine energy technologies, processes for engaging the public, and public perceptions of ocean interventions. As they worked through the dimensions, they described feeling both intrigued and overwhelmed by the density of the framework, noting that some dimensions

(such as political, technological, and educational) felt more intuitive, while others (such as particle) were harder to grasp. Their contributions clustered around symbolic and mythological dimensions, particularly as they discussed how stories, fears, and narratives about the ocean shape public responses to marine interventions and energy projects. Participants reflected on how education rarely addresses where energy comes from, how engineering training often treats materials as simply "available," and how assumptions about supply chains and risk obscure the historical, labor, and ecological footprints of marine energy infrastructures.

When the group moved into Part 4, they collectively chose the *symbolic* dimension as the focus for their justice discussion. Using the justice glossary as a prompt, they connected symbolic meanings of marine energy to intergenerational justice, climate justice, procedural justice, recognition justice, ecological justice, racial justice, carceral and spectral justice, drawing on examples ranging from regulatory regimes and protest surveillance to burial grounds, lithium mining, and submerged cultural heritage. One participant brought up the tension between the rights of the people and the rights of the government, "thinking about how we approach, you know, the right to dissent, the right to protest against something, and the tools of state occupation." Another participant further complicated the tension, "You think about supply chain, lithium mining out in Eastern Oregon, Nevada, where you've got potentially disrupting burial grounds in order to extract lithium … it's not just that, you know, future death. It's that past death." Participants emphasized that decisions about marine interventions always create "winners and losers" and that more-than-human beings are often the ones sacrificed "for the greater good." Another participant brought it back to reframing the narrative and mindset to policy shifts: "Now, depending on, you know, how deeply you've swallowed sort of the future climate disaster story, it's the opposite. If we don't do things, the harm will occur. And so we have to overcome decades of sort of regulatory structure and kind of mythology in our own minds in order to do something. And it may require completely rewriting, you know, the regulations that have been entrenched. And also just completely flipping the mindset of the way to proceed is to legally block things, which is costly, lengthy, and often a waste of time, and could probably sink a lot of efforts to intervene and try to save some things."

In the final reflection on what might be "response-able" or designable, they highlighted the need to redistribute power and expand participatory justice, to make room for ceremony and grief in engagement processes, and to humanize expert-led interventions in ways that acknowledge both the risks and the deep emotional stakes of working in and with the ocean.

Workshop 3 Overview: Circular Economy

The *Entangled Justice: Circular Economy* workshop brought together practitioners who work on sharing infrastructures, reuse, policy, and community organizing. Although participants began by mapping their "it"s (tool libraries, reuse ecosystems, and policy and economic structures) across the 14 dimensions (see Appendix Figure 6.3.3), the subsequent discussion gravitated toward the mythological and economic dimensions and unfolded into a wide-ranging conversation about fear, capitalism, colonialism, and complicity.

First, participants recognized that their work in the circular economy is as much mythological as it is material. While their daily activities center on tools, reuse systems, and logistics, they noted that stories and fantasies do much of the work of making circular economy legible and compelling. One participant observed that their field is "pretty material," yet "so much of what we do is this telling the story of what we do," including sharing a "fantasy of a sustainable mall" that people respond to enthusiastically. Circular economy, in this sense, operates as a narrative device that frames climate futures and mobilizes desire, not just as a technical framework for resource management. Building on this, the group questioned whose futures are being imagined through these myths. Participants critiqued how dominant circular imaginaries often reproduce Western, white, higher-education-informed ideals of the "good life." One participant described these as "Western normative" visions of a "perfect future," rooted in "white identities" and "individual constructions of collectivist ideals," where collective life is imagined but the individual self remains at the center. This raised concerns that even ostensibly radical circular futures may still be grounded in narrow cultural assumptions, marginalizing those who do not see themselves reflected in these narratives.

A related thread concerned the limiting effects of capitalism and fear on imagination. Participants spoke candidly about how the scale of systemic change can feel overwhelming and paralyzing. One person noted that imagining the complete restructuring of capitalism felt "so daunting and unrealistic… I just want to go to bed," and instead described trying to calibrate a fantasy that "pushes and shifts" the system without becoming "unfathomable" or impossible to break down "into chunks, particles, as it were." Others linked this to deep-seated fears about survival, competition, and scarcity, suggesting that "everything we can imagine is still contained" within the parameters of capitalist logics. These reflections challenge us to imagine beyond the technical or practical, into the speculative, emotional, and existential.

The conversation also foregrounded how the circular economy is both old and potentially co-opted. Participants stressed that many circular practices such as sharing, repair, and reuse, have long predated the term. As one put it, circular economy can appear as a

"culturally appropriated, sexy term," marketed as a novel innovation even though "none of this is new." Another remarked that when people ask how they "came up with" circular ideas, the honest answer is simply "you mean sharing… that's how society started." At the same time, there was concern that the phrase "circular economy" is already being folded into corporate greenwashing, much like "sustainability" before it, and that large companies "have more resources" and may move faster to instrumentalize the term. Participants also noted that the countries leading circular policy and discourse are often the same "large Western economies" that historically drove colonial development agendas, suggesting that circular economy risks repeating familiar patterns of authority and leadership even as it seeks to challenge extractive systems.

Justice concerns in this workshop centered heavily on economic inequality, access, and who bears the burdens and benefits of circular initiatives. One participant emphasized the "huge gap in time [and] capital" between those with abundant access and those without, arguing that large economies and institutions often drive environmental decisions whose impacts are borne by people with "less buy-in" and fewer resources. Another linked this critique to lived experience of poverty, stressing that knowing what is "right" for low-income communities or people in the Global South requires asking them directly, rather than exporting surplus goods or solutions designed elsewhere. These reflections point toward distributive, social, and racial justice issues embedded in circular economy work and challenge any assumption that circular interventions are automatically equitable.

When the group moved into Part 4, they collectively chose the *mythological* dimension as the focus for their justice discussion. Throughout the conversation, participants linked these insights to questions of justice, particularly social, racial, environmental, distributive, and participatory justice, asking whose futures are being imagined, who is invited into circular spaces, who remains excluded or overburdened, and how their own work sits inside systems of capitalism, complicity, and "slow violence."

Participants appreciated the justice glossary and the dimensional mapping as a way to name and connect different forms of injustice, but also described feeling overwhelmed when trying to identify "what is next" or "what is actionable." One person said they "start to crumble" when thinking about the actionable implications of the analysis, noting that the work can become "too philosophical" or "too theoretical" to easily translate into concrete steps. In response, others identified connections to "small justices," incremental, situated actions that accumulate toward larger change. Participants also discussed the importance of power redistribution (for instance, using their own positionality to "help others have the ability to respond"), and the need to understand why some people "self-select" into circular spaces (tool libraries, repair events, secondhand shopping) while others do not. Questions of who shows up, who feels represented, and who has the time and capacity to participate

point toward participatory and recognition justice as critical, ongoing challenges for circular economy practice.

Insights from the Workshops

In this section, I unpack insights that emerged across all three *Entangled Justice* workshops. Looking across climate migration, marine energy, and circular economy, the following cross-cutting insights emerged:

Noticing injustice

Across the workshops, participants used the dimensions and justice glossary to notice how many different kinds of injustice are entangled in their work, especially in the marine energy context. Rather than treating "justice" as a single, abstract concern, they identified intergenerational, carceral, recognition, ecological, and distributive justice as distinct but interconnected lenses. One participant framed clean energy transitions in terms of responsibility to "future generations" and what we are "leaving" behind. Another described a developer-funded police force "spying on protesters and activists" as a hidden carceral justice issue. Others pointed to public anxiety about "doing harm in the marine space," the need to "better represent and account for other species," and the reality that "there are winners and losers" in any intervention, along with the question of "who gets to decide" what is sacrificed "for the so called greater good." This noticing of injustice also appeared in a tension between "nature based" and "technology based" climate solutions. One participant observed that it feels "very unfair to ask… nature that is already… not functioning in a healthy way to take on this extra burden of solving our industrial problem," raising questions about ecological and distributive justice when damaged ecosystems are expected to absorb further impacts. Across the three workshops, this practice of noticing injustice became a way to surface whose voices, lives, and worlds are at stake, and to begin imagining more equitable forms of response.

Intergenerational responsibility and small justices

Across all three workshops, participants wrestled with a tension between responsibility to future generations and the reality that they often only feel able to act through small, situated changes in the present.

In the marine energy workshop, participants framed their work as a direct obligation to those who will live with the consequences of today's decisions. One participant explained that clean energy transitions are driven in part by a concern for those who come after us:

> "A lot of that underpins that notion of what are we doing for future generations? And what are we leaving? You know, and that's kind of one of the main impetus

> behind a lot of the marine renewable energy push is intergenerational justice and climate justice as well. But more timescale for intergenerational."

Similar concerns surfaced in the climate migration workshop as participants connected species, water, and ancestors across long ecological and historical timescales, and in the circular economy workshop as they discussed the slow violence of extraction, waste, and inaction. Across contexts, participants treated intergenerational justice as a core motivation and as a haunting question that sits behind their everyday work: what kind of world are we actively making livable or unlivable for those who are not yet here.

At the same time, participants described how difficult it feels to translate this expansive, long-term responsibility into concrete, near-term action. The circular economy group articulated this most explicitly. One participant reflected on how the human-centered design frame helps them see more clearly what is at stake, but also leaves them overwhelmed when they try to decide what to actually do next:

> "I love this, I love what the human centered design brings to it, but when I think of the actionable, like, what is the next… or what to take away, I start to crumble and try to think about, you know, how does this influence the other things, and so then I have to get locked up again, like it accelerated expansion and contraction."

At the same time, they valued how the justice framings helped them name what their work is really about: "The way that that is brought into the conversation about what this truly brings to what we're doing, what our work is, and how we can change things."

Across workshops, this back and forth between long-term, intergenerational obligation and the limits of what feels actionable in the present pointed toward the importance of small justices. Participants repeatedly returned to the idea that they may not be able to solve systemic problems at scale, but they can make incremental, situated interventions in their own domains, and that these smaller efforts matter when understood as part of a broader, collective movement for more just futures.

Capitalism vs. sustainability paradox

Across the circular economy workshop, participants grappled with a core tension: how to pursue sustainability and justice from within a capitalist system that relies on competition, profit, and growth. They noted that circular initiatives often remain constrained by the very economic logics they seek to transform. As one participant put it, "to continue to be in this society, it has to rely on competition, it has to rely on some kind of basically, capitalist iteration of bottom lines, business plans, etc." Another described the prospect of systemic

change as emotionally exhausting, saying that “thinking of totally reshaping capitalism is incredibly daunting and unrealistic to me to the point where I just want to go to bed.”

Participants also pointed to widespread greenwashing as a symptom of this paradox. They observed that “sustainability has been completely greenwashed” and reported seeing “how many goddamn horrible companies are greenwashing us, this packaging Circular Economy already.” Together, these reflections highlight a shared concern that circular and sustainable futures risk being absorbed into existing market logics, where the language of sustainability is used to maintain profits rather than redistribute power or reduce harm. This paradox surfaced as a reminder that any serious engagement with sustainability must also contend with the structures and incentives of capitalism itself.

Public perceptions and contested assumptions

Across the workshops, participants emphasized that public perception shapes what kinds of climate and sustainability initiatives become politically and socially viable. They noted that many climate action plans rest on “taken for granted assumptions about what needs to be done,” including “assumptions about energy usage [and] what is an acceptable level of energy usage for society.” These assumptions often remain unexamined in expert-led planning and can clash with community values, fears, or lived experiences. Participants framed this as a gap in current engagement practices, where the public is frequently asked to endorse predefined solutions rather than invited to question, critique, and imagine alternatives. They argued that effective climate action requires spaces where people can challenge underlying logics, surface their concerns, and co-develop responses, rather than simply being asked to accept what technical or policy experts present as necessary or inevitable.

In the marine energy workshop, participants linked similar concerns to ocean interventions and tribal and coastal communities. They described strong public anxiety about “doing harm in the marine space,” especially when proposals involve chemicals or structures in already stressed ecosystems, and noted that these fears are shaped by long histories of regulation, extraction, and loss. Participants described how existing regulatory and cultural frameworks, such as the Clean Water Act, have taught people to equate action with harm and inaction with safety, which complicates public acceptance of new interventions.

In the climate migration workshop, public perception appeared more obliquely, through reflections on which species and habitats capture attention and care. Participants contrasted the attention and resources directed toward iconic species, such as orca whales, with the neglect of less “appealing” beings like Columbia spotted frogs. One participant explained that frogs are not listed as endangered because “we don’t know enough about them,” and

that people see them as “unseen and gross and unimportant,” so “scientists haven’t studied them and money hasn’t been put in it.” Another introduced the concept of charismatic megafauna as species that are “particularly beautiful or iconic,” noting that “because of their charisma, we are more maybe empathetic to their condition, you know, to their suffering, to their success to their survival.” This framing raised questions about who decides which species are charismatic and whose values count in that decision. Participants noted that if Indigenous communities were the reference point, salmon might stand at the center, yet salmon are not consistently treated as charismatic in mainstream public discourse, even though orcas depend on chinook salmon for survival. These discussions highlighted a recognition and ecological justice concern. Public perception, shaped by Western aesthetics and media, directs care, funding, and policy attention toward some lives and not others, even when overlooked species are “equally if not more at risk” and equally crucial to their ecosystems.

In the circular economy workshop, participants noted that many popular narratives of circular futures are shaped by Western norms and higher-education cultures, describing them as “Western normative” and rooted in “white identities’ perfect future.” Participants discussed who shows up to tool libraries, repair events, and reuse spaces, and who does not. They connected this to identity, power, and representation, asking how people from marginalized groups “who don’t see themselves represented in this dominant conversation space” might perceive circular initiatives, and how businesses rooted in competitive logics may see community sharing projects as “100 percent competition.” Taken together, these reflections make visible how racialized identities, institutional cultures, economic factors, and media narratives are tightly entangled in shaping who feels invited into circular futures and on what terms. At the same time, they observed that broader media and entertainment are saturated with stories about the climate crisis, which creates an opening for alternative myths. As one participant explained, “we see a lot of movies and media that’s about problems that circular economy could be part of the solution for and so people get really excited when you can share a myth that shows circular economy as a solution.” Here, myth and story function as both a critique of existing imaginaries and a way to propose more just ones. Together, these discussions suggest that public perception is an active field of contested meanings, fears, and hopes that climate and justice oriented design must engage with deliberately.

Insights from the Interviews

The post-workshop interviews provided participants with an opportunity to reflect on their experience in the workshop. They give us insight into how participants made sense of the workshop’s structure, the tensions and connections that emerged, and the ways in which they related the experience to their own work and values.

Overall Impressions

Across participants, overall impressions of the *Entangled Justice* workshop were strongly positive, though reflections varied depending on individual comfort with theory, technology, and facilitation structure. Participants consistently described the workshop as intellectually stimulating, perspective-shifting, and creatively engaging, even when it felt complex or demanding. For some, the workshop offered an unusual way to explore familiar issues. One participant remarked that it helped them "approach problems that I am working to actively solve" from a completely new angle, while another called it "academic therapy," a space to untangle ideas and recognize "connections between random bits and scraps" of knowledge. Others described it as "a rigorous self-study" that prompted reflection on what they knew, where gaps existed, and how their own assumptions shaped their work.

Participants also saw clear potential for adapting the format to other contexts particularly education, research collaboration, and policy dialogue. One participant envisioned using the framework "as a team-building exercise at the start of a research project," while another said it could be "a really useful way of thinking about complex problems" with students or policymakers. The exercise's structured yet open format encouraged "reflecting on how we think," helping people become more aware of the implicit values embedded in their approaches to environmental and social challenges.

Several participants emphasized the workshop's applicability beyond academia but noted that the concepts might need to be translated for different audiences. One suggested simplifying the glossary of justices "into one-line definitions" for accessibility, while another recommended "distilling down" the 14 dimensions to make them approachable for community groups or planning boards. Another reflected that it would be more effective if participants "knew what they were walking away with"—clarity on whether the goal was reflection, action, or both.

Participants also identified opportunities for improving facilitation and preparation. Common suggestions included providing materials or examples beforehand, offering more structured guidance during the session, and allowing more time for discussion and depth. As one participant summarized, "Each dimension is so rich that it could be its own chapter of conversation," suggesting that future versions could benefit from longer or multi-session formats.

Despite these logistical challenges, many felt personally and professionally impacted by the workshop. Some described being newly motivated to integrate justice frameworks into their own research, while others found renewed appreciation for reflective practice itself.

One participant admitted, “I’m so resistant to reflection at this moment, but I’ll probably be reflecting on reflection,” capturing the self-referential awareness the workshop encouraged. Another said it provided “a tangible way to discuss things like design,” giving new language and tools for addressing complexity.

Several participants, particularly those engaged in ongoing community, ecological, or policy work, saw direct relevance to their professional practice. One mentioned that the workshop “helped me recognize how these wicked problems are entangled,” and expressed an interest in securing funding to “do this kind of work more and collaborating more.” Another likened the experience to “my favorite seminar classes” where ideas circulate freely, describing it as “very rewarding.” In sum, participants viewed the *Entangled Justice* workshop as a valuable space for reimagining how justice and sustainability are practiced, providing a rare opportunity to slow down, connect across disciplines, and collectively rethink the ethics of design and environmental action.

Overall workshop experience

Across interviews, participants described the *Entangled Justice* workshops as structured, focused, and conceptually rich, with a clear core pattern: choose a specific “it,” map it across the 14 dimensions, and then relate those mappings to different forms of justice in group discussion. One participant summarized the circular economy workshop as a space to explore “how we see our identity in circular economy and how justice, different justices relate to those attributes.” Others described “working through an understanding of some of the frameworks that informed [the] entangled justice approach,” choosing a topic such as seasonal wave deployments or climate migration, and then “answer[ing] the questions in those dimensions on the wheel” before “link[ing] some of those dimensions to the aspects of justice.” A climate migration participant characterized it as gathering “a group of like-minded experts” and using prompts to “uncover some of the different aspects of our research,” then taking one facet and discussing it “in terms of some of the different types of justice.”

Many participants found the content intellectually stimulating but also dense and demanding. They appreciated the chance to “dissect the idea… into those segments,” and to see how environmental, climate, and racial justice “relate to a lot of what I… understand,” yet several noted that each dimension felt “so rich that they could be their own chapters of conversation.” Some people highlighted how the format supported their own thinking styles. One participant described the wheel as “really conducive,” because they could “just kind of scroll to a certain spot,” brainstorm, then “move on to the next one” when a dimension felt exhausted. Others described needing more orientation or time, using metaphors like “reading the airplane manual as I was flying” to convey the cognitive load of learning the framework and working in Miro at the same time.

Experiences of the digital format were mixed. Several participants engaged smoothly with the shared Miro board and saw the visual layout as helpful, while others experienced significant technological friction. One person reported that a small screen made text "almost illegible," and that they struggled to "interact with the online interface" and follow the Zoom conversation at once. A few suggested that having the materials and justice glossary in advance, or as printable handouts, would have allowed them to process new terminology beforehand and "participate in a more useful way." Overall, participants understood their role as contributing situated expertise, brainstorming across dimensions, and experimenting with justice framings. They described the workshops as "really interesting" and "cool," while also acknowledging that the combination of new concepts, time constraints, and online tools created a challenging learning environment.

Workshop content and format

Across interviews, participants described the workshop content as both exciting and demanding. Many appreciated how the 14 dimensions and justice terms pushed them to see familiar work in unfamiliar ways. One circular economy participant said the dimensions "really challenged me to relate to the question… with a different point of reference" and to surface organizational practices they had "developed but not necessarily ever dissected." Others felt the framework "gets at the heart" of the social, philosophical, and symbolic context around technical work, offering a rare chance to think with peers about "big existential things" like mythology, symbolism, and justice that usually sit outside everyday practice. Several people also highlighted how rich and expansive the justice glossary felt, noting that the "breadth… actually stood out" and that the list made large systemic questions feel more "approachable in the justice realm."

At the same time, the very richness of the content created cognitive overload. Fourteen dimensions in fifteen minutes felt like "a lot for 15 minutes," and several participants admitted they gravitated to a subset that felt either comfortably familiar or productively "in the middle" of their expertise. For some, dimensions like particle, symbolic, and mythological initially felt "weird" or "foreign," but those same categories often became the most generative once people engaged them. Across interviews, people converged on similar suggestions for improving content and format. They recommended sharing the 14 dimensions and justice glossary ahead of time so participants could sit with the terminology and avoid spending precious minutes "just reading the definitions." Some suggested either fewer dimensions or more time, framing the current version as a "buffet" where only a portion is realistically usable in a short session. Others proposed small adjustments to reduce jargon, de-emphasize dense theoretical citations in the intro, and include at least one simple, grounded example of an "entanglement map" in practice. Finally, several participants expressed a desire for longer or follow-up sessions where they

could go deeper into specific dimensions and justice terms, and spend more time in collaborative discussion rather than racing the clock.

Participants described the justice list as fascinating but overwhelming in the available time. Some said they "did not have time to engage with that much," and that the justice terms "could have been a whole session" on their own. Many asked for examples or case studies that show how someone else had mapped an "it" across dimensions or applied multiple justice framings, to help them "fire up" their own thinking.

The format itself drew mixed but generally positive reactions. Many people liked Miro as a collective mapping tool, especially the ability to "see everyone's thoughts in one place" and to structure information spatially rather than in a scrolling document. Participants noted that sticky notes forced them to "distill" ideas to a kernel, which they saw as a strength. Others, especially those on small screens or with different learning styles, struggled with the density of text and the need to zoom in and out, saying it was "hard to conceptualize the whole" while navigating individual segments. Several suggested simplifying the text inside the wheel, separating labels from detailed prompts, or providing a printable or separate reference document.

Collaborative learning

Participants consistently described the collaborative aspect as energising and idea-generating. Seeing each other's notes in real time helped people "jog" new connections and notice gaps in their own thinking. One person noted that when someone shared an insight, "it would kind of jog me and make a connection to something else," and that the group discussion around justice terms was where "everyone's connections they made independently met." Others described the group as "really smart," with each participant bringing different situational and community contexts, even when they shared similar demographic and regional backgrounds. Several interviewees said they would like to use this method as a team-building exercise or a way to start a research project, because it surfaces how many "layers" and perspectives exist around a single issue.

Existing relationships shaped the collaborative dynamic. Some found it easier to speak openly about justice and politics because they already trusted the others in the room, which "helped… facilitate that discussion" and allowed them to "shoot from the hip" without fear of judgment. At the same time, a few people felt that knowing the group too well "colored my explanation" and led them to leave things implicit that might not be legible to outsiders. In workshops where participants did not know each other as well, collaboration felt more like listening in than co-producing something. One person said it felt "not so

collaborative as informative," because the group shared ideas but did not work together toward a concrete joint outcome.

Several highlighted learning from others' critiques of their own narratives, such as questioning whether a favored circular economy "myth" was truly inclusive or carried hidden injustices. Others pointed to new concepts introduced by peers, like charismatic megafauna or unfamiliar justice terms, as moments that expanded how they saw their work. Participants appreciated starting with solo "quiet time" to fill the wheel, then moving into shared discussion; many felt that pairing or co-writing from the start would have constrained their thinking.

At the same time, collaboration brought clear challenges. Time pressure meant people spent much of the session typing and reading rather than talking, which limited deeper exchange. Some participants did not want to "compete for airspace" and disengaged when discussions felt too diffuse or dominated by a few voices. Others struggled to multitask between Zoom, Miro, and group conversation, particularly on small screens, and felt rushed or disoriented. Several suggested more structure to support equitable collaboration, such as briefly co-populating a single dimension as a guided example, focusing everyone on one shared "it," using explicit step-up / step-back norms, or carving out more time to dwell on a small number of threads instead of staying "shallow, wide" across many. Despite these constraints, most participants described the collaborative element as valuable and would welcome a longer, more focused version of the workshop to deepen that shared work.

Perspective shifts through dimensions, justice, and futures

Across interviews, participants described justice in relation to wicked problems as a constant presence in their work and thinking. Many said they think about them "daily" or "every day," with one joking "how many hours a day am I awake?" For others, the topics surfaced mainly in academic or professional spaces but still carried emotional weight. One participant noted that reading about climate change often "just kind of depresses me." Those with community or activist backgrounds described justice as inseparable from their everyday practice, calling it "where I live" or "uncomfortable, comfortable territory."

Participants generally saw the workshop as a way to deepen and complicate how justice is understood. It created space to "build the stairs to the second floor," as one described it, offering steps between abstract climate goals and lived realities. Others valued how the activity revealed that "there's more than one right answer" and "multiple realities" within complex environmental issues. For some, it was a confirmation of ideas they already held;

for others, it opened “a whole new suite of questions” about climate, species, and migration that their jobs rarely allow.

The glossary of justices stood out as one of the most impactful elements. Participants said it expanded their understanding of justice. One researcher reflected, “I had no idea there was like, all of these kinds of justice,” while another said new concepts such as multispecies and spectral justice sparked “a lot of light bulbs.” Participants noted how these framings could reshape how institutions approach fairness, moving equity beyond hiring practices to include impacts on “future generations, non-human species, and other dimensions of the world we share.”

Engaging with the 14 dimensions also brought a mix of curiosity, excitement, and overwhelm. One participant called it “fun and overwhelming,” while another decided to “just write stuff” without worrying about being right or wrong. Others struggled with feeling “like I was reading the airplane manual as I was flying,” revealing how challenging it can be to navigate new conceptual terrain while trying to contribute meaningfully. Many made intentional choices about where to focus, for example, some avoided topics they knew deeply to leave space for others, while others sought out less-populated areas of the map to diversify contributions.

Although the workshop didn’t radically shift participants’ ethics, it deepened how they approach justice and the futures it implies. Several spoke of confronting their own assumptions: one noted that it helped them “dial up” awareness of biases in the futures they imagine, while another said it reinforced that “solutions don’t really exist and we just redistribute tensions.” Others emphasized the value of “democratizing knowledge” and “connective tissue work” that links different disciplines and perspectives, pushing experts to “work outside their areas of expertise,” creating “a space to struggle” together rather than defaulting to siloed solutions.

Ultimately, participants viewed the experience as an invitation to think differently. Some suggested adapting the exercise for policy or planning spaces to counter defeatism and broaden participation, believing that “maybe you could make it better if you’re in a group.” Others said it highlighted how much more effort is needed to include a “full range of perspectives” in environmental decision-making. For many, the workshop’s greatest contribution was helping them slow down, question taken-for-granted assumptions, and see justice as an ongoing, relational process.

Shifting Framing and Evaluation Across Lab–Field–Showroom

Across the *Entangled Justice* investigation, my criteria for "what counts" as a successful intervention shifted as the work moved from lab to field to showroom. In the lab settings of the "Entanglement Methods" DRG and *Politics of Imaginaries* workshop, evaluation centered on whether mapping, dimensions, and ignorance as a resource could be made legible and usable at all: could participants grasp the 14 dimensions, translate them into visual artifacts, and begin to see their work differently? In the *Diffraction* pilot workshop at the PMEC conference and the topic-focused *Entangled Justice* workshops, that framing broadened to ask how deeply the methods could travel into participants' ongoing work in climate migration, marine energy, and the circular economy, and whether the dimensions and justice glossary actually helped them surface tensions, gaps, and complicities they had not been able to articulate before. By the time the final workshops operated in a field–showroom hybrid, evaluation became less about specific outputs and more about the trajectories participants imagined afterwards: using the knowledge maps in their labs, adapting the exercises for policy committees, or reworking the glossary for community-facing processes. In this sense, *Entangled Justice* reframed evaluation as a question of portability and reconfiguration, whether a method born in the lab could remain generative when re-situated in highly constrained, politically charged domains, and whether the "showroom" moment could double as a rehearsal for future, locally owned iterations of the work.

Tensions and Unexpected Dynamics

The workshops and interviews also exposed frictions that complicate any simple narrative of success. Several participants described the sessions as "fun," enlivening, or even a kind of "academic therapy," yet this sense of play sat alongside climate anxiety, feelings of overwhelm, and the weight of ongoing injustice. Some were sharply aware of the opportunity costs of spending two hours in reflective conversation while otherwise overworked on moving their goals forward, and expressed a desire for clearer goals, timeboxing, and tangible outcomes; others valued the looseness as a way to struggle productively with not knowing. The justice glossary and 14 dimensions were experienced both as a "pretty freakin cool glossary" and as "chaotic" or cognitively heavy, prompting suggestions for one-line versions, more scaffolding, or distilling concepts for non-academic or community audiences. I view these tensions as signals of where the methods rub against structural constraints of time, expertise, and representation, and they now inform how I imagine the *designing for entangled speculation* framework to build in clearer shared purposes while still leaving room for friction, discomfort, and partial understanding.

Step 4: Reflect and Disseminate

As the third and final investigation in this dissertation, *Entangled Justice* reshapes how I understand the overall RtD arc I have been tracing. *Post(-)human Hazmat* began with speculative artifacts that made emergent entanglements of risk visible; *Speculative F/Actors* shifted to collaborative discussion and scenario-building to probe how participants inhabit and negotiate climate futures; *Entangled Justice* folds these strands back into the live problem-spaces where practitioners already grapple with climate migration, marine energy, and circular economies. My reflections on these investigations are directly tied to the development of the *Designing for Entangled Speculation* framework. The collective insights, tensions, and dissemination trajectories outlined across the three investigations seed the framework I articulate in the next chapter.

Conceptual and Methodological Insights

Conceptually, *Entangled Justice* extends the earlier investigations by making questions of justice central rather than implicit in practices of entangled speculation. This investigation also asks how people already working in areas related to wicked problems might reframe their work through multiple justice lenses and mapped dimensions of knowledge and ignorance. The 14 dimensions and justice glossary formalize a way of slowing down expertise, redistributing attention from familiar metrics (e.g., efficiency, carbon capture) toward less-visible histories, labor, procedures, and more-than-human obligations. Methodologically, the workshop demonstrates how mapping can function simultaneously as an analytic tool, speculative device, and conversational scaffold: participants use the maps to externalize what they know, to notice what is missing, and to imagine different futures and responsibilities. The interviews suggest that this combination of situated and shared mapping, and justice framings offers a repeatable pattern that can be adapted for labs, interdisciplinary teams, and policy processes, and it becomes one of the core ingredients of the *Designing for Entangled Speculation* framework that I develop in Chapter 7.

Dissemination and Audience Response

Dissemination for *Entangled Justice* is still very much in progress, and this open-endedness is itself part of the story. Beyond the immediate participants, (many of whom expressed interest in using the methods with their students, research labs, or planning processes) the primary "audience" so far has been my committee and the research communities around design justice, marine energy, circular economy, and climate adaptation. More broadly, *Entangled Justice* is one of the anchors for the *Designing for Entangled Speculation* framework that I propose in the next chapter, where I repackage the methods, artifacts, and lessons from all three investigations into a set of patterns that other designers and researchers can

adapt. In this sense, dissemination is about turning the workshops themselves into portable, adaptable techniques for thinking and acting with entangled justice.

Step 5: Repeat

In the formal structure of this dissertation, *Entangled Justice* is the last investigation in the RtD cycle, so "repeat" no longer means running another study so much as carrying forward what has been learned into a new register. The next chapter takes up this task by reading across *Post(-)human Hazmat*, *Speculative F/Actors,* and *Entangled Justice* to articulate *Designing for Entangled Speculation* as a framework for working with entanglements in different ways. New questions emerge here that are less about any single workshop and more about the range of speculation these investigations collectively open: How do different methods invite people to notice different knots in an entanglement? What shifts when speculation is oriented toward emergent hazards, toward future imaginaries, or toward reconfiguring justice in ongoing practice? And how might these approaches be combined, sequenced, or adapted for diverse publics, from community scientists and tool library organizers to engineers, policymakers, and students? Treating this "final" step as a beginning, I use these questions to guide the transition from individual case studies to a transferable, though necessarily partial and revisable, framework for designing with entangled futures.

Appendix

6.1. Dimensions used in the *Entangled Justice* workshop in Figure 6.2:

Below are the 14 Dimensions from "Writing the Implosion" (Dumit, 2014):[191]

Labor dimensions: How was it produced and who is involved in its production? Are there stages in its production? Where has it traveled to and from? What are the histories of its productions? Who maintains these processes of production? Where are they maintained? How is it used and how is using it seen as labor, or not? What forms of labor and work incorporate it or make use of it? Is it used up? If not, how is it passed on, transferred, communicated? What routes do these processes take? What kinds of actors (human and nonhuman) are involved, and what kinds are excluded?

Professional/Epistemological dimensions: How is knowledge of the process and its production demarcated and professionalized? What kinds of knowledge count in talking about it? What kind of professionals are involved in making expert decisions regarding its development, production, and dissemination? How are each of these stages funded? In projecting its future use? What kinds of controversies of this knowledge are happening? Who is involved? In what kinds of institutions do they work? How is it articulated by medical, legal, governmental, religious, psychological, engineering, military, economic, academic, new age, and educational professionals? What are the political-economic histories of this?

Material dimensions: What materials are involved in its production and maintenance? Where have these materials come from? How are they disposed of? What hazards are considered among these materials? What are the labor dimensions of these material productions? What are the global, economic, and political dimensions of their use? What are the histories, sciences, and political dimensions of these materials? How do these help constitute it?

Technological dimensions: What kinds of technologies and machines enable it to be produced and maintained? What technologies are joined with it? Who has access to these machines and technologies? What are their histories? What sorts of information technologies are involved? What are the political, economic, bodily, labor, and historical dimensions of these technologies? How do they help constitute it?

Context and situatedness: Where does it appear in the world? How does it appear and next to what or in what? What activities or ways of life enable one to come across it? What kinds of audiences is it addressed to? Who is excluded in these addresses? When can it appear? What is the rhythm of its appearance? How does this matter?

Political dimensions: What kinds of local, national, and international bodies claim jurisdiction over it? What bodies play a part in approving it (e.g., lobbyists, patents,

[191]Dumit J (2014) Writing the Implosion: Teaching the World One Thing at a Time. Cultural Anthropology 29: 344–362.

corporate sponsorship, etc.)? What are the histories of regulations concerning it? How do these regulations help constitute it? How is it understood in terms of political positions in the world? How can we articulate the ways it is understood with political discourses? How is it hegemonic—in what ways can we see it as marshaling our consent to dominant orders? What kinds of legislation affect it? How do political considerations make use of it? What are the political positions as seen through the lens of this artifact (they often vary by artifact and moment)? How does this matter?

Economic dimensions: The process as commodity: how is it marketed, purchased, consumed? Where and by whom? How is it involved in a world marketplace? What kinds of capital, debt, credit, and labor relations are involved in producing, marketing, and circulating it? Who sells it? How are costs calculated? How are risks calculated? By whom and when? What are the histories and materialities of those relations? Who is involved at each stage and how are differences in power situated? How do these help constitute it?

Textual dimensions: What texts are involved in it? What texts refer to it? What kinds of texts? Who produces them and who reads them? Where and in what organizations and institutions are the texts produced and read? What are the histories of these texts and how are they funded? What kinds of textual associations can be made? How does this matter?

Bodily/organic dimensions: How are bodies related to it? What forms of attention, affect, emotion, and cognition are involved? Are there particular ways in which we think of ourselves that also involve or sustain this process? What kinds of bodies, including nonhumans, and bodily relations are involved in producing it? What kinds make use of it? How are these bodies and relations gendered? Are there racial, gendered, differently abled, or other group identifications that help construct these bodies? What ways of life are involved? What are the histories of all these relations? How do these help constitute it?

Historical dimensions: What concepts refer to it? What are the histories of these concepts? Was it invented, when and by whom? Are there different and competing versions of its histories? Who tells these histories? How has it traveled historically? Repeat the above dimensions for each aspect of its history. How do these help constitute it?

Particle Dimensions: How can the process be divided up? What are its parts? What are its stages? Treating each part or stage as a process, repeat the above analysis.

Educational dimensions: How does it appear in our socialization? When do we learn about it in school? During the rest of life? What kinds of people/ bodies get to learn about it? How much do we learn about it? What aspects of it are avoided? What are the histories of teaching about it? How does this matter?

Mythological dimensions: What roles does it play in fantasies? What kinds of national narratives make use of it? How does it appear in entertainment? What other grand narratives, stories, and strong associations involve it (e.g., progress, risk, joy, fear, science, militarism, success, decline, horror, self-improvement, financial security, nuclear family,

motherhood, fatherhood, independence, adolescence, democracy, origin stories, stories of difference, privilege, death, pornography, sports)? How do these matter?

Symbolic dimensions: What are the many different ways in which it can be taken as a symbol? How does this process serve in symbolic systems? What sorts of ideas, metaphors, movements, ideologies, and the like are associated with it? For whom are these relevant, to whom do they matter, and what contests over meaning are they involved in? What are the histories of these meanings and contests over meaning? How do they matter?

6.2. Glossary of Justices used in the Entangled Justice workshop in Figure 6.2:

Below are the 21 Justices from, *The Promise of Multispecies Justice* (Chao, Bolender, and Kirksey, 2022):[192]

Carceral justice involves imprisonment. This form of retributive justice entails punishing people for violating the law. Multispecies justice does not involve carceral justice but is instead allied with the prison abolition movement that envisions a world without cages or chains (see Lara).1

Intergenerational justice is concerned with the scope and nature of relations, responsibilities, and obligations as these manifest across different generations.8 It demands that institutions consider the potential impacts of their actions on the well-being of future human and other-than-human generations and their duties and responsibilities to generations past (see Lyons).

Restorative justice is a response to injustice that focuses on restitution and resolution of issues arising from a crime or transgression. Mediation and conflict resolution can be used by victims, offenders, and a broader community to restore relations creatively (see Clark).14

Small justices are achieved through everyday incremental shifts and slight alterations rather than sweeping structural transformations. These micropolitical interventions, or microbiopolitical articulations, involve changes in daily patterns of thought and behavior.15 Small justices operate in the middle of worlds, mediating rather than remediating multispecies relations. Often ambiguous and deceptively mundane, these little justices take difference and dissent as starting points for new cosmopolitical possibilities (see Ihar). 26

Climate justice foregrounds the disproportionately severe social, economic, health, and intergenerational impacts of climate change on vulnerable human groups. Advocates for climate justice suggest that functioning environments are a necessary condition for the fulfilment of other, intersectional justices—like environmental justice, social justice, and racial justice (see introduction).2

Multiworld justice is grounded in the phenomenology of matter itself. It approaches justice through the lens of lived experience, within and at the edges of dynamic worlds. In contrast to framing justice as potentiality, or what might be, multiworld justice attends to justice as actuality, or what just is (see Marder).

[192] Chao, Sophie, Karin Bolender, and Eben Kirksey. 2022. "Introduction: Who Benefits from Multispecies Justice?" *The Promise of Multispecies Justice*. Duke University Press. (3).

Social justice involves the fair and egalitarian treatment of all members of a given society in relation to questions of equity, access, well-being, participation, and rights. Movements for social justice are particularly concerned with achieving recognition, remedy, and redress for segments of society who are systematically marginalized (see introduction).16

Competitive justice highlights the conflicts among different ideals about justice that proliferate within the political asymmetries, contestations, and forms of resistance that accompany the entanglement of species. By identifying conflicts between wildlife management and human flourishing, as well 24 Sophie Chao and Eben Kirksey as forms of discrimination within the category of the human itself, identifying competition in the field of justice might help produce future coalitions within terrains marked by power differentials (see Paredes).3

Participatory justice demands the equal, inclusive, and transparent participation of all parties in the development, enactment, and governance of justicerelated institutions and practices. This framework addresses the challenge of reconciling disparate and often conflicting interests, values, and beliefs in achieving agreement over what counts as justice (see Lyons).9

Spectral justice troubles the boundaries between life, death, and the afterlife. The haunting force of ghosts can prompt the living to redress injury and repair damaged relations. Incomplete and inchoate in form and substance, spectral justice involves difficult negotiations across immanent and transcendent realms (see Govindrajan).

Patchy justice materializes in fragments amidst uneven conditions of livability. Inspired by ideas about the "Patchy Anthropocene," this form of justice arises through grassroots oppositional movements, feral proliferations, and counter-hegemonic hopes that emerge in unstable places and uncertain times (see introduction; see afterword).10

Distributive justice is classically concerned with the distribution of benefits and burdens within society. Some approach this model with strict egalitarian principles, while others attend to how context governs the distribution of wealth and welfare. Emerging theories of bioproportionality expand the subjects of distributive justice beyond the human to effect an equitable partitioning of planetary resources across different species (see introduction). 4

Substantive justice involves fair outcomes. Critical race theorists have considered how legal procedures often fail to account for substantive advantages and disadvantages at play across racial lines. Rather than focus on due process, or formal equality before the law, these theorists point to the substance of rulings when considering if justice has been done (see introduction).17

Procedural justice involves due processes. Some believe that simply following the correct procedure results in an equitable outcome, regardless of whether distributive or restorative justice has ultimately been achieved (see introduction).11

Ecological justice calls for recognition of other species as legitimate bearers of rights and recipients of resources. It seeks to develop institutional arrangements that can accommodate the claims and affordances of diverse creatures within its decision-making processes.5

Racial justice involves the fair treatment of people regardless of their racial identity. Beyond the mere absence of inequity and discrimination, racial justice calls for the establishment of institutional mechanisms that proactively sustain racial equity and reckon fully with the historical and colonial roots of racial violence (see Lara; see introduction).12

Transformative justice aims to achieve change in social, political, technical, or biological systems. Some victims of interpersonal violence or rape have used this approach to educate offenders and community members instead of pursuing punishment through the criminal or carceral system. Perpetrators of injustice may also seek to transform themselves in order to repair what they have damaged (see Clark).18

Environmental justice aims to counter and redress the various forms of environmental discrimination that cause marginalized and racialized communities to bear the disproportionate burden of environmental harms, such as vulnerability to air pollution and water contamination and exposures to hazardous waste and toxic chemicals (see Ishiyama and TallBear; also see introduction).6

Recognition justice attends to how different beings gain or lose standing as a result of structural, institutional, cultural, legal, and economic regimes and attendant hierarchies of worth. It involves recognizing that past and ongoing legacies of unequal treatment, discrimination, and exclusion continue to produce just conditions of life for some and not others.13

Transitional justice often entails fraught compromises as fragmented groups work to attain peace amidst large-scale armed conflict and human rights abuses. The process often involves recognizing, addressing, and remedying past wrongs through formal mechanisms including war-crime tribunals, truth commissions, criminal prosecutions, reparations programs, as well as efforts to support the physical and psychological healing of victims of war and violence (see Lyons).19

Generative justice is a bottom-up justice that emerges from collective resistance to hegemonic forces through peer-to-peer networks, open-source software movements, queer affiliations, agroecology projects, and Indigenous federations. This form of justice celebrates the consequential role of other life forms—bacteria, plants, fungi, and insects—within nested loops of multispecies regeneration (see Lee).7

6.3. Dimension Wheels from the *Entangled Justice* workshops

Appendix Figure 6.3.1. *Climate Migration dimension wheel.*

Appendix Figure 6.3.2. *Marine Energy dimension wheel.*

Appendix Figure 6.3.3. *Circular Economy dimension wheel.*

Chapter 7: Designing for Entangled Speculation Framework

7.1 Reframing Entanglement and Method

In the formal structure of this dissertation, *Entangled Justice* (see Chapter 6) is the last investigation in the RtD cycle, so "repeat" no longer means running another study so much as carrying forward what has been learned into a new register. In this chapter, the questions shift to the range of speculation that the three investigations collectively make possible. How do different configurations of speculative engagement invite participants to notice different knots in an entanglement and to name what is held in tension? What shifts when speculation orients toward emergent tensions of hazard and care, toward future imaginaries, or toward reconfiguring justice in ongoing practice? How might these speculative approaches combine, sequence, or adapt for other wicked situations and diverse participants, from community scientists and tool library organizers to engineers, policymakers, and students?

Treating this "final" step as a beginning, this chapter responds to those questions by reading across *Post(-)human Hazmat*, *Speculative F/Actors*, and *Entangled Justice* to articulate *Designing for Entangled Speculation* as a framework for approaching complex and wicked problems. It gathers together the conceptual, methodological, and empirical strands from previous chapters into conversation with each other in a diffractive way, identifying approaches for developing entangled practices.

7.1.1 Locating this chapter in the dissertation arc

Across the dissertation, the pieces of this framework appear gradually and in partial form. Chapter 1 introduced *Designing for Entangled Speculation* (DES) as the central contribution and argued that design speculation can operate as a mode of inquiry that responds to wicked problems by engaging their entangled conditions. Chapter 2 developed four concepts from quantum entanglement as design orientations, proposing *superposition*, *observer effect*, *interconnectedness*, and *nonlocality* and *nonlinearity* as lenses for thinking about how speculation opens multiplicities and potentials, foreground the ethics of noticing, materialize relations, and attend to multi-scalular consequences. Chapter 3 introduced a Research through Design (RtD) methodology situated within Lab, Field, and Showroom environments, which provided the scaffolding for how each investigation was organized around an iterative, five step cycle (select, design, evaluate, and reflect & disseminate, and repeat). Chapters 4, 5, and 6 then elaborated three investigations as case studies and theory building sites, each experimenting with different ways to bring entanglement concepts into speculative practice.

This chapter builds on that arc and returns to the three investigations as a composite dataset and a set of situated experiments of *entangled speculation*. I analyze how they relate to one another, to my own expanding understanding of what entanglement could mean, to the four entanglement concepts, and to the broader goal of *designing for entangled speculation*.

7.1.2 From relational entanglement to quantum entanglement

From the early conception of this project, I approached entanglement primarily as a way to understand relationality as it appears in HCI, anthropology, the social sciences, and the humanities. In these fields, each discipline provides vocabularies for interdependence, situated knowledge, and ethical responsibility within complex systems. As I worked with these literatures, I understood entanglement as a powerful way to talk about complex relations, but I also noticed that entanglement was often invoked without being clearly defined, and used interchangeably with more familiar notions such as relations or networks. I expanded my search for meanings of entanglement and found Karen Barad's *Meeting the Universe Halfway*[193] and Denise Ferreira da Silva's *Unpayable Debt*[194] to be gateways into conceptions of entanglement in quantum physics and insights into how they relate wicked problems.

Karen Barad, feminist theorist and physicist, argues that quantum entanglement shows us that things don't exist as independent entities before they relate. Instead, entities emerge through what they call "intra-actions." They write: "To be entangled is not simply to be intertwined with another, as in the joining of separate entities, but to lack an independent, self-contained existence" (Barad, 2007).[195] In this view, matter and meaning are inseparably co-constituted: "The very nature of materiality is an entanglement. Matter itself is always already open to, or rather entangled with, the 'Other'" (Barad, 2007).[196] They use this insight to develop their theory of *agential realism*, where agency is distributed across both human and non-human actors, and where knowing is always a material-discursive practice (Barad, 2007).[197] In developing their theory of agential realism, Barad draws on Niels Bohr's interpretation of quantum physics to challenge classical notions of independent objects and to reconceptualize reality in ways that open space for new paradigms of thought and being. As they explain:

> "What he is doing is calling into question an entire tradition in the history of Western metaphysics: the belief that the world is populated with individual things with their own independent sets of determinate properties. The lesson that Bohr

[193] Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning*. Durham, NC: Duke University Press, 2007.
[194] Ferreira da Silva, D. (2022). *Unpayable debt*. MIT Press.
[195] Barad, Karen. *Meeting the Universe Halfway*. 2007. p.
[196] Barad, Karen. *Meeting the Universe Halfway*. 2007. p.
[197] Barad, Karen. *Meeting the Universe Halfway*. 2007. p.

> takes from quantum physics is very deep and profound: there aren't little things wandering aimlessly in the void that possess the complete set of properties that Newtonian physics assumes (e.g., position and momentum); rather, there is something fundamental about the nature of measurement interactions such that, given a particular measuring apparatus, certain properties become determinate, while others are specifically excluded. Which properties become determinate is not governed by the desires or will of the experimenter but rather by the specificity of the experimental apparatus." (Barad, 1996, p. 19)[198]

Barad's work on agential realism reconfigures entanglement as an ontological and ethical condition rather than a metaphor (Barad, 2007).[199] For Barad, beings do not preexist their relations. They emerge through intra-actions in which matter, meaning, and measurement co-constitute each other, and observation actively participates in the world's becoming (Barad, 2007).[200]

Denise Ferreira da Silva takes quantum nonlocality seriously as a way to rethink sociality, arguing that a nonlocal universe does not support a modern subject organized around linear time, spatial separation, and discrete identities (da Silva, 2022).[201] Entanglement, in her account, demands an imagination of difference that does not presuppose separability or stable, bounded entities (da Silva, 2022).[202] She describes these principles—*separability*, the assumption that entities exist independently; *determinacy*, the belief that properties are fixed and knowable; and *sequentiality*, the linear temporal logic that orders existence—as the metaphysical ground upon which Western knowledge and social hierarchies have been built. She proposes instead "a radical shift in how we approach matter and form" (da Silva, 2016, p. 2),[203] one that dissolves these assumptions and rethinks difference itself. This shift involves turning away from what she calls "the thinking of cultural difference," a framework inaugurated by figures like Franz Boas, whose claim that "social, rather than biological aspects account for the variation of mental (moral and intellectual) contents" introduced a temporal and spatial model of cultural variation (da Silva, 2016, p. 3).[204] While Boas's work marked an important methodological break in cultural anthropology, it nonetheless remained bound to the metaphysical structure of separability. As da Silva notes, even as anthropology departed from biological determinism, it still relied on "a knowledge

[198] Barad, Karen. *Meeting the Universe Halfway.* 1996. p.19)
[199] Barad, Karen. *Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning.* Durham, NC: Duke University Press, 2007.
[200] Barad, Karen. *Meeting the Universe Halfway.* 2007.
[201] Ferreira da Silva, D. *Unpayable debt*. MIT Press. (2022).
[202] Ferreira da Silva, D.*Unpayable debt*. (2022).
[203] da Silva, Denise Ferreira. "On difference without separability." *Catalogue of the 32a São Paulo Art Biennial,'Incerteza viva'(Living Uncertainty)* (2016): 57-65. p.2.
[204] da Silva, "On difference without separability." p.3.

program modeled after Newtonian and Einsteinian physics, in which separability is the privileged ontological principle" (da Silva, 2016, p. *5*).[205]

In contrast, da Silva's notion of "the entangled world" (da Silva, 2016, p. 4)[206] draws on the quantum concept of nonlocality to envision a universe where entities are not discrete but mutually implicated. She writes, "What nonlocality exposes is a more complex reality in which everything has both actual (spacetime) and a virtual (nonlocal) existence. If so, then why not conceive of human existence in the same manner?" (da Silva, 2016, p. *5*)[207]. This turn toward virtuality allows da Silva to reconceptualize human difference itself as a product of entanglement rather than separation: "Why not assume that beyond their physical (bodily and geographic) conditions of existence... humans exist entangled with everything else (animate and inanimate) in the universe?" (da Silva, 2016, p. *5*).[208]

Through this lens, difference without separability becomes a radical reconstitution. "When nonlocality guides our imaging of the universe, difference is not a manifestation of an unresolvable estrangement, but the expression of an elementary entanglement" (da Silva, 2016, p. *5*).[209] In such an entangled world, "sociality becomes neither the cause nor the effect of relations involving separate existants, but the uncertain condition under which everything that exists is a singular expression of each and every actual-virtual other existant" (da Silva, 2016, p. *5*).[210] This reorientation opens an ethical horizon beyond the colonial and capitalist frameworks that depend on separability. Da Silva's difference without separability thus calls for a way of thinking—and being—in which the social, the material, and the cosmic are understood as inseparably entangled.

Reading entanglement through quantum physics opens possibilities for reimagining wicked problems beyond the limitations imposed by traditional framings of what is happening and what is possible. This perspective compels us to ask deep ontological questions that unsettle foundational assumptions about what it means to be human, and epistemological questions that challenge traditional conceptions of reality. In doing so, it invites a critical rethinking of the colonial and capitalist systems that rely on extractive logics of separation, between self and other, subject and object, human and nonhuman. Earlier relational understandings of entanglement often remained trapped within these very power structures, focused on dynamics between entities without escaping their underlying dualisms. The quantum reading of entanglement, by contrast, is more

[205] da Silva, "On difference without separability." .p.*5*.
[206] da Silva, "On difference without separability." .p.4.
[207] da Silva, "On difference without separability." .p.*5*.
[208] da Silva, "On difference without separability." .p.*5*.
[209] da Silva, "On difference without separability." .p.*5*.
[210] da Silva, "On difference without separability." .p.*5*.

generative, creating *goods for speculating*,[211] new potentials for ethical, political, and speculative engagement (see 7.2.3 "Outputs as '*goods for speculating*' about entanglement").

In this chapter, I work with that tension and blend relational uses of entanglement in design alongside quantum interpretations that foreground inseparability, the collapse of possibilities through observation, and the limits of linear, isolated thinking. This connection between relational and quantum conceptions of entanglement opens new possibilities for design, ethics, and justice, and it shapes how I interpret the three investigations and the framework that emerges from them.

7.1.3 Research through Design, staying with the trouble, and diffraction

The recursive aspects of the RtD approach allowed me to stay with the trouble of what "entanglement" can mean as an analytical lens. I used each investigation as moments to test and challenge my developing understanding of entanglement as a concept through practice. RtD's iterative cycle of selecting, designing, evaluating, reflecting, and disseminating allowed me to see how different workshop formats, materials, and publics produced different contexts for engaging entanglement. Some relations became clear and actionable, while others stayed obscured. This is what makes RtD so effective for theory building and framework development. Concepts do not remain abstract. They are shaped, constrained, and redefined through concrete material engagements.

To analyze these shifts, I draw on *diffraction*, a method developed in feminist science studies (Haraway 1992;[212] Barad 2007).[213] Diffraction comes from wave physics, where patterns of interference reveal how elements interact. As a research method, diffraction focuses on understanding phenomena through the relations they produce, rather than treating them as isolated objects. It differs from triangulation, which assumes a stable object of study. A diffractive reading instead asks how differences emerge, how they intersect, how they matter, and what they reveal.

In what follows, I use this diffractive orientation to read across *Post(-)human Hazmat*, *Speculative F/Actors*, and *Entangled Justice*, tracing relations to each entanglement concept as it moves through different materials, sites, and publics, revealing a deeper understanding of *entangled speculation*. I first compare how each investigation engages *superposition, observer effect, interconnectedness,* and *nonlocality* and *nonlinearity* and how they position speculation along a spectrum from *abstract to concrete* and from *fictional to situated*. I then analyze how

[211] A riff on what Tharp and Tharp call "goods for thinking." Bruce M. Tharp and Stephanie M. Tharp, *Discursive Design: Critical, Speculative, and Alternative Things* (MIT Press, 2019). pp. 7.
[212] Haraway, Donna. "The promises of monsters: A regenerative politics for inappropriate/d others." In Cultural studies, pp. 295-337. Routledge, 2013.
[213] Barad, Karen. Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning. duke university Press, 2007.

different outputs, from stories and dioramas to maps of knowledge and ignorance, work as *goods for speculating* with entangled futures. Finally, I synthesize these insights into the *Designing for Entangled Speculation* framework, which I present as a set of orientations and modes for designing with entangled futures in diverse contexts.

7.2 Reading Across the Three Investigations

This section reads across *Post(-)human Hazmat*, *Speculative F/Actors*, and *Entangled Justice* to describe how each occupies a different position in the design space and how each brings entanglement concepts into practice. I provide a high level description and comparison where they sit on a two by two map that runs from abstract to concrete and from fictional to situated, see Figure 7.1 below. I then describe how the four entanglement concepts appear across the three investigations and close with a comparison of their outputs as *goods for speculating* with entangled futures.

7.2.1 Comparative overview and speculative–entangled

The three investigations differ in their aims, participants, and degrees of grounding. *Post(-)human Hazmat* was the most abstract and extended investigation. Across ten sessions, participants worked with dense theoretical readings and developed speculative stories about posthuman, multispecies, and hazardous futures. The work centered on individual narrative development that participants brought back to the group for feedback. Speculation here operated at the level of imagined worlds, characters, and ethical provocations rather than specific sites or infrastructures.

Speculative F/Actors: Climate Futures moved this work into shared and materially grounded speculation. In this investigation, small groups of mostly unfamiliar participants met for a short, intensive workshop focused on climate futures in a situated specific region. Participants built dioramas using tiles that represented a range of factors and actors, and differently colored strings to trace bodily/organic, technological, and political relations among them.

Entangled Justice turned most directly toward real world contexts that focus on a wicked problem area that already involved active work and expertise, such as climate migration, marine energy, and circular economy. Participants included practitioners, researchers, and community members with direct experience in these domains. Rather than build fictional worlds, they developed shared knowledge maps and “ignorance maps” that surfaced gaps, tensions, and injustices in ongoing systems.

Plotted on a two by two map, with one axis running from abstract to concrete and the other from fictional to situated, the three investigations trace a loose trajectory (see Figure 7.1

below). *Post(-)human Hazmat* sits near the abstract and fictional corner, where speculative work explores broad shifts in ontology and multispecies relations without direct reference to specific projects or policies. *Speculative F/Actors* occupies a middle region, remaining speculative and playful but anchored in a particular place and in recognizable climate related issues. *Entangled Justice* sits closer to the concrete and situated corner, where participants focus on existing infrastructures, institutions, and practices while still reaching toward alternative futures. This map helps describe how each workshop opens different possibilities for engaging with entangled speculation.

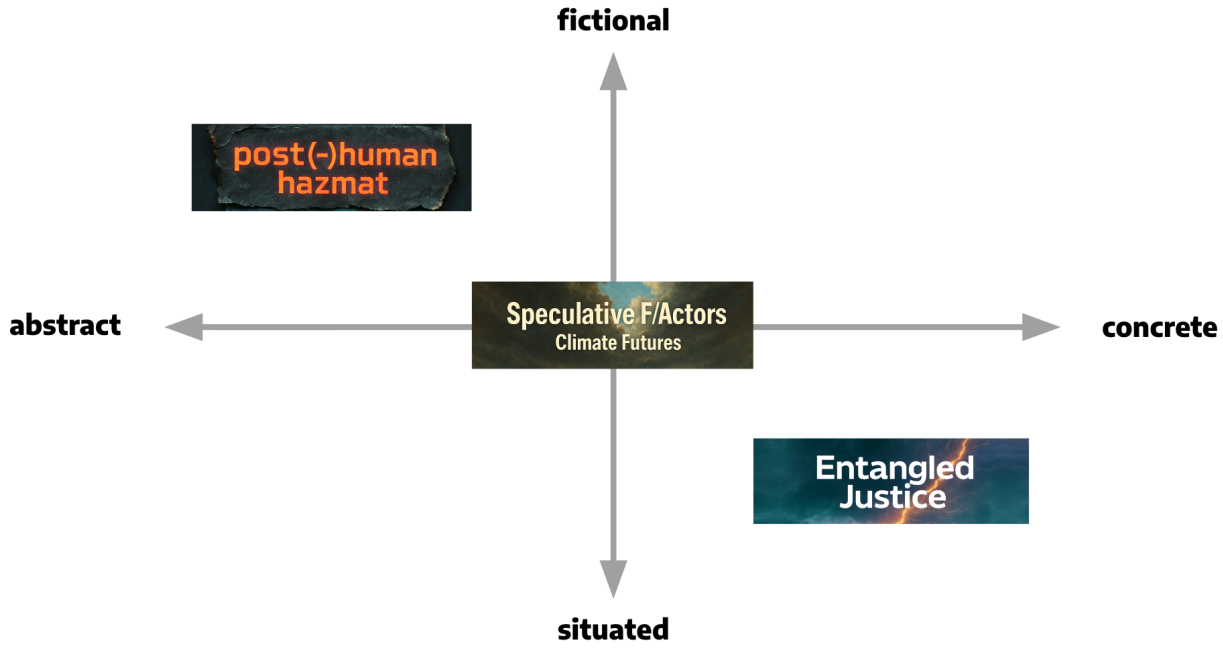

Figure 7.1. *Two by two graph, mapping abstract to concrete and fictional to situated.*

Diffractive Reading Across Workshops

Diffraction, in quantum physics, describes how waves spread and overlap when they encounter an obstacle or pass through an opening, producing patterns of interference, intensification, and cancellation. In experiments such as the double-slit experiment, particles like photons or electrons exhibit wave-like behavior, generating interference patterns that cannot be explained by treating them as discrete, independent entities. These patterns emerge from the relational conditions of the experimental setup itself, where outcomes are probabilistic and produced through interaction rather than revealing a pre-existing state (Feynman, Leighton, & Sands, 1965).[214] Diffraction thus demonstrates that what is observed is not simply a reflection of an underlying object, but a pattern created through relations, positionality, and contextual constraints.

[214] Feynman, Richard P., Robert B. Leighton, Matthew Sands, and Everett M. Hafner. 1965. "The Feynman Lectures on Physics, Vol. I." *American Journal of Physics* 33 (9): 750–752.

In feminist STS and sociocultural theory, diffraction has been taken up as a methodological approach for reading insights through one another rather than comparing them against a fixed discrete reference point. As Karen Barad argues, diffractive reading attends to patterns of difference that matter, foregrounding how meanings emerge through interference, entanglement, and intra-action rather than through reflection or triangulation (Barad, 2007).[215] Rather than seeking convergence or validation across cases, diffractive analysis traces how perspectives overlap, amplify, or unsettle one another, allowing new insights to emerge from their relational crossings.

Reading *Post(-)human Hazmat* through the later *Entangled Justice* investigations surfaces forms of interference that were not legible when each workshop was considered in iterative sequence. In *Post(-)human Hazmat*, the speculative distance from present-day constraints enabled participants to imagine multispecies futures with a high degree of imaginative freedom, care, and narrative openness. When viewed diffractively through *Entangled Justice*, however, this openness also reveals an absence: the relative invisibility of infrastructural, political, and institutional constraints that shape how care is enacted in practice. What initially appeared as a strength of abstraction in *Post(-)human Hazmat* becomes, through this reading, a site where the limits of speculative detachment come into focus. This interference reconfigures the significance of the two investigations, showing how imaginative excess and contextual grounding operate in tension rather than as progressive stages.

Conversely, reading *Entangled Justice* through *Post(-)human Hazmat* brings a different interference to the foreground. In *Entangled Justice*, participants' deep grounding in lived expertise and real-world problem contexts often constrained their capacity to engage in far-reaching speculation. Through the lens of *Post(-)human Hazmat*, this constraint appears not simply as realism but as a form of imaginative compression produced by proximity to institutional accountability, urgency, and responsibility. This diffractive reading highlights how speculative capacity is unevenly distributed across contexts and how grounding, while ethically necessary, can foreclose certain futures before they are fully articulated. Together, these interferences suggest that speculative openness and situated constraint are not opposing modes to be resolved, but entangled conditions that require deliberate design attention. Diffractive analysis thus becomes a method for tracing how different workshop configurations reveal and obscure possibilities in relation to one another, rather than a means of synthesizing them into a single, linear account.

7.2.2 Entanglement concepts in practice

The four entanglement concepts appear across the three investigations in distinct but related ways. *Superposition*, the quantum phenomena where entangled particles can exist in

[215] Barad, Karen. 2007. Meeting the Universe Halfway: Quantum Physics and the Entanglement of Matter and Meaning. Durham, NC: Duke University Press., chapt. 2.

multiple states of potential prior to being observed, as an invitation to hold multiple potentialities in tension, was most pronounced in *Post(-)human Hazmat*. Participants experimented with overlapping identities, timelines, and more than human relations as they drafted and revised their stories. They often held several possible directions open before choosing how to resolve a narrative. In *Speculative F/Actors*, superposition appeared as participants negotiated which futures their diorama would show. They discussed possible changes, extinctions, and interventions, and the diorama held many of these possibilities at once until the group agreed where to place tiles and how to represent change. In *Entangled Justice*, superposition existed but faced stronger constraints. Participants could imagine different trajectories for climate migration or circular economy, but existing policies, technologies, and power relations narrowed what counted as plausible.

Observer effect, understood as the way measurement, observation, and intervention collapse potential futures, also played out differently across the three settings. In *Post(-)human Hazmat*, participants' interpretive choices about theory and their own positionality shaped which aspects of entanglement appeared in their stories. The act of writing collapsed some possibilities and foregrounded others. In *Speculative F/Actors*, the observer effect took a more material form. Decisions about where to place a tile or how to connect elements with string visibly committed the group to one version of the future rather than another. In *Entangled Justice*, the observer effect became more explicitly ethical and epistemic. What participants chose to include on knowledge and ignorance maps, whose experience they treated as central, and which harms they named or left unspoken all shaped what futures came into view and which remained unaddressed.

Interconnectedness, as an orientation toward relations that exceed neat boundaries, moved from symbolic to structural across the investigations. In *Post(-)human Hazmat*, interconnectedness appeared in narrative form, as participants imagined entangled lives across species, technologies, and environments. In *Speculative F/Actors*, interconnectedness became more concrete. Strings, tiles, and physical arrangements made relations visible and debatable. Participants could point to specific links and discuss how one factor influenced another. In *Entangled Justice*, interconnectedness extended across systems. Participants mapped relations among policies, infrastructures, energy regimes, ecological conditions, and social inequities. The focus shifted from local narrative entanglement to entanglement within and across institutional and material structures.

Nonlocality and nonlinearity, understood here as cross scale effects and feedback loops that disrupt simple logics of cause and effect, became more explicit as the investigations turned toward specific domains. In *Post(-)human Hazmat*, participants played with nonlinear time and strange couplings in their stories, but these temporal structures often remained implicit. In *Speculative F/Actors*, nonlinearity became more central through prompts that

asked participants to imagine changes fifty years into the future and to trace how those changes rippled through their diorama. In *Entangled Justice*, nonlocality and nonlinearity were most explicit. Participants recognized that actions in one place or at one moment could produce consequences far away or decades later, and that these effects were often unevenly distributed. Conversations about climate migration, for example, highlighted how policies, borders, and histories of extraction shaped movement and vulnerability in ways that did not follow simple cause and effect.

Taken together, these patterns show that the entanglement concepts did not function as abstract categories layered on top of the investigations. As a design researcher, I put these concepts to work in specific workshops, materials, publics, and problem areas, and in doing so amplified their meaning in each study. The cross reading in this section sets up the framework that follows by showing how superposition, observer effect, interconnectedness, and nonlocality and nonlinearity appear and shift across different forms of speculative engagement.

7.2.3 Outputs as "goods for speculating" about entanglement

The outputs of the three investigations also differ and play distinct roles in how participants might think with entanglement. These outputs foregrounded what participants knew, did not know, or could not know about the systems they worked within. They directed attention toward gaps, contradictions, and tensions rather than toward resolved futures. As *goods for speculating*, these outputs helped participants and me trace where power and information concentrate, where harm and care accumulate, and where possibilities for justice oriented change might emerge. Across the three investigations, these stories, dioramas, relational maps, and justice diagrams support different kinds of speculative engagement with entangled futures, *goods for speculating*.

Post(-)human Hazmat produced individual speculative stories that participants wrote and revised over time. These narratives captured complex entangled situations from the vantage point of particular characters and worlds. They worked well for exploring how it feels to inhabit entangled conditions and for experimenting with ethical questions in a less constrained space. The stories and final zine act as *goods for speculating* because they translate dense theoretical material into narrative and visual forms that people can engage with directly. As participants revised their stories of entangled value tensions, they made choices about how concepts like multispecies care, toxicity, and survival would appear in scenes, characters, and imagery. The zine brought these pieces together in a format that made the theoretical work accessible and discursive.

Speculative F/Actors produced collective dioramas of climate futures, annotated tiles, and relational string maps. These outputs materialized entanglements in a shared physical space. They allowed participants to see and adjust relations in real time and to return to the configuration later for analysis. These outputs functioned as *goods for speculating* because they combined affective engagement, spatial reasoning, and collaborative negotiation. They make abstract climate dynamics tangible and allow participants to explore them through hands-on worldbuilding. The workshop kit's varied materials, including laser cut tiles, natural textures, and strings for mapping political, technological, and ecological relations, were designed to ground complex systems in playful and concrete interactions. As participants arranged tiles, added locally meaningful elements, and debated what was meaningful to trace, the artifacts surfaced nonlinear connections and prompted shifts in interpretation that often only became visible through the material process. Dioramas and maps thus served less as finished products and more as provocations that exposed relational logics and imaginative tensions. In this way, the outputs extended the speculative work beyond the workshop, offering visual and spatial prompts that continued to generate reflection on climate futures and entanglement.

The outputs from *Entangled Justice* function as *goods for speculating* because the collaborative knowledge maps created on the shared Miro board make participants' expertise, assumptions, and blind spots visible in real time. These maps visualize how the 14 dimensions fill out unevenly, showing areas of dense knowledge and gaps that form the "ignorance maps" participants then use as prompts for deeper reflection. As participants added, rearranged, and annotated sticky notes, the board grew into a layered representation of collective understanding that supported conversation. The maps worked as cognitive tools that traced how justice, accountability, and situated expertise entered into and reshaped the group's speculative thinking across the session.

By reading across these outputs, I treat them not as isolated artifacts, but as a set of complementary tools for designing and speculating with entanglement in practice. They invite different forms of reasoning, feeling, and collaboration, and they privilege different scales and problem framings. This variety is not a weakness. It is a resource for the framework that follows.

7.3 Designing for Entangled Speculation (DES) Framework

In this section, I present the *Designing for Entangled Speculation* (DES) framework which consists of four design orientations and a modified RtD cycle using diffraction and entangled lab-field-showroom environments. In my work, workshops function as the primary medium through which entanglement becomes material and actionable. The materials—string, tiles, maps, written narratives, and collaborative boards—create

conditions where participants can make relations visible, debatable, and open to intervention. The orientations that follow emerge from these workshop-based engagements, but they are articulated at a level that allows others to apply them within their own material and disciplinary contexts. Whether a designer works through models, prototypes, datasets, performances, or policy artifacts, these orientations invite translation into whatever materials best support making entanglement tangible in practice.

7.3.1 Four orientations for designing for entangled speculation

The four quantum entanglement concepts introduced in Chapter 2 translate into four design orientations in this framework, each describing how to shape speculative work so that it takes entanglement seriously, rather than treating it as a loose synonym for relation or complexity.

Design Orientation 1: Catalyze potentialities and resist closure (superposition)

Across the three investigations, *superposition* appeared whenever participants kept multiple futures, identities, or system trajectories in play at the same time. In *Post(-)human Hazmat*, this showed up in parallel storylines and competing interpretations of theory that coexisted before participants chose which ones to carry forward. In *Speculative F/Actors*, groups entertained several possible configurations of their diorama and multiple ways a climate future might unfold before committing tiles and strings to the board. In *Entangled Justice*, participants held different diagnoses and possible interventions in mind, even as institutional and technical constraints narrowed what they considered plausible.

As a design orientation, holding plural potentialities means creating conditions where multiple futures can sit side by side without forcing early resolution. It asks designers to slow the move to closure and to treat conflicting visions as a resource for learning rather than a problem to solve. This orientation emphasizes processes that surface, name, and keep track of divergent possibilities so that groups can see what is at stake when they eventually collapse them into a particular direction.

To invoke this orientation, design speculative engagements that:

- **Hold multiple futures open.** Support the coexistence of several potential futures before any single direction is chosen. Delay closure so groups can explore what different paths reveal about stakes, impacts, or values.
- **Materialize multiple meanings.** Design materials that support branching and revision, such as modular tiles or layered maps that can hold more than one version at once. Invite participants to sketch or narrate several parallel scenarios before choosing one to deepen.

- **Surface contradictory values and desires.** Superposition treats contradictions as productive. Competing priorities are held in view so their ethical stakes become legible.

Design Orientation 2: Notice and collapse futures responsibly (observer effect)

The *observer effect* became visible whenever groups made choices that committed them to one version of the future and set others aside. In *Post(-)human Hazmat*, this happened when participants decided which theoretical threads to center in their stories and which to leave implicit. In *Speculative F/Actors*, each decision to place a tile, draw a string, or mark a change fixed a particular reading of the system and its subsequent future trajectories. In *Entangled Justice*, decisions about what to include on knowledge and ignorance maps, whose experience to foreground, and which harms to name actively shaped which futures participants could imagine as possible or desirable.

As a design orientation, collapsing futures responsibly means treating these decision points as ethical and epistemic events, not as neutral steps in a process. It calls for making choices visible, naming who is involved in them, and reflecting on what those choices exclude. This orientation asks designers and participants to recognize that speculative work does not simply reveal the future. It participates in shaping which futures appear legible and actionable.

To invoke this orientation, design speculative engagements that:

- **Recognize choice as intervention**. Every speculative move (placing an object, naming a problem, selecting a storyline) is an intervention that collapses possibilities into concrete direction. Designers acknowledge that choices do not simply describe futures; they help produce them.
- **Make decision moments visible.** Identify who is driving decisions, whose voice is shaping the direction, and how power circulates in the moment of collapse. This shifts collapse from an automatic action to an accountable one. Groups pause to surface what was just chosen, how it was chosen, and what alternatives existed at that moment.
- **Attend to exclusions and erasures.** When one future becomes dominant, others fall away. Responsible collapse involves explicitly noticing which perspectives, communities, or more-than-human actors get left out, and treating those absences as analytically important.
- **Use collapse to clarify stakes and consequences.** The moment of collapse reveals what matters most. Identifying why a group chooses one future over another helps surface values, fears, and priorities that may not appear through brainstorming alone.

Design Orientation 3: Make relations tangible and contestable (interconnectedness)

Interconnectedness emerged in different material forms as participants worked to see and reason about relations. In *Post(-)human Hazmat*, it appeared in narrative form, as stories that linked human and more than human lives, technologies, and environments. In *Speculative F/Actors*, dioramas, tiles, and string maps turned relations into visible and adjustable structures that participants could point to and debate. *Entangled Justice* extended interconnectedness into structural and institutional domains as participants mapped links among policies, infrastructures, ecological systems, and social inequities.

As a design orientation, making relations tangible and contestable means externalizing relationships so that they become available for shared attention and critique. It treats maps, artifacts, and physical arrangements not as neutral representations but as tools to ask who or what is included, who or what is missing, and how power circulates through the network. This orientation emphasizes the importance of giving participants ways to redraw, remove, or add relations so that they can challenge existing configurations.

To invoke this orientation, design speculative engagements that:

- **Support the reconfiguration of relations as a speculative act.** Because entities emerge through their relations, changing relations is a form of worldmaking. This orientation gives participants tools to redraw, remove, or add connections to experiment with alternative arrangements and to explore how different relational patterns produce different futures.
- **Reveal and unsettle boundaries that appear fixed.** Because entangled systems exceed neat edges, this orientation draws attention to boundaries as constructs rather than facts. Invites participants to challenge ontological and epistemological and ask questions about what counts as inside or outside the system and how those boundaries produce exclusions.
- **Treat relations as the fundamental units of analysis.** Following Barad's account of intra-action, interconnectedness understands relations as the primary focus, not the entities themselves. Designers work from the assumption that people, materials, infrastructures, and ecologies emerge through relationships, not prior to them. For example, use simple materials such as string, sticky notes, tiles, or layered diagrams to visualize relations and invite participants to move, add, or remove elements. Ask explicit questions about what or who sits off the map and what that absence reveals about the boundaries of the system under discussion.
- **Surface power that circulates through relations.** Interconnectedness is not just about connectivity. It is about the flows of power, dependence, extraction, and care that shape how relations operate. Making relations tangible helps expose asymmetries, blind spots, and systemic harms that often remain hidden.

Design Orientation 4: Engage across scales and logics (nonlocality and nonlinearity)

Nonlocality and nonlinearity became more explicit as investigations turned toward situated contexts. In *Post(-)human Hazmat*, nonlinear time and strange couplings appeared in story worlds, but often stayed implicit. In *Speculative F/Actors*, prompts that asked participants to imagine changes fifty years into the future and to trace ripple effects through the diorama brought longer temporal horizons into view. *Entangled Justice* made cross scale reasoning central, as participants connected local experiences to global energy regimes, historical patterns of extraction, and intergenerational justice.

As a design principle, thinking and feeling across scales means inviting participants to move between temporal and spatial levels and to sit with the uneven impacts that appear when they do so. It asks designers to foreground long term and distant consequences and to recognize the emotional responses that can emerge when people confront slow violence or deferred harm. This orientation treats scale shifting as both an analytic and an affective practice.

To invoke this orientation, design speculative engagements that:

- **Reject linear, separable explanations of complex worlds.** Drawing from da Silva's critique of separability and sequentiality, this orientation rejects simple cause–effect thinking. Treat futures, harms, and responsibilities as distributed across time, space, and actors rather than located in one place or moment.
- **Hold the actual and the virtual together.** Following da Silva's notion that entities have both spacetime (actual) and nonlocal (virtual) existence, this orientation invites speculative work that considers both what is happening and what else could be happening in the same moment. The virtual becomes an active resource for imagining otherwise.
- **Use scale-shifting to unsettle dominant logics.** Moving across temporal and spatial scales becomes a tool for challenging colonial, capitalist assumptions that tie agency, identity, and responsibility to discrete individuals or bounded communities. Scale-shifting exposes how those logics fail and opens space for imagining entangled forms of sociality and justice.
- **Treat emotions as part of cross-scale reasoning.** Thinking across scales is not only analytic. Confronting slow violence, deep time, or intergenerational responsibility produces grief, fear, care, and uncertainty. This orientation holds these feelings as legitimate forms of knowledge that can shape ethical commitments.

7.3.2 A Diffractive RtD approach for designing for entangled speculation

The RtD approach provided strong conditions for developing this framework, as discussed in Section 7.1.3. Concluding the three rounds of the five-step cycle with a diffractive reading

helped the framework take shape. Reflecting on this process, I see how RtD and diffraction work well together: RtD offers an iterative, practice-based structure for generating material from which concepts can emerge, and diffraction provides a way to read across those iterations without collapsing them into a single narrative. Because RtD is cyclical, each investigation produces only a partial view. The diffractive moment takes stock of what the investigations collectively disclose by attending to patterned differences and interferences.

Together, these practices point toward Diffractive RtD as a design and research approach for entangled speculation. Diffractive RtD incorporates intentional moments within or after an RtD cycle where investigators read across investigations and the outputs produced (prototypes, workshops, artifacts, and documentation) to see how concepts shift as they move through different contexts. Diffractive RtD treats the multiple investigations as entangling events whose relations matter for theory building. A diffractive interlude can occur after a single cycle, but it becomes especially generative when placed after multiple cycles, where conceptual and material variation across investigations can surface.

7.3.3 Entangled lab-field-showroom environments for designing for entangled speculation

Reconsidering the Lab–Field–Showroom environments through an entangled speculation lens also shifts how they function in RtD. Rather than discrete stages or settings that can have overlap, these environments are themselves entangled conditions that co-produce each other. *Lab* work shapes what becomes possible in the Field; *Field* encounters introduce constraints and obligations that reshape what the Lab needs to generate next; and *Showroom* presentations feed back into both the Lab and the Field by reframing how the work is understood and who it is accountable to. Thinking with these environments as an entangled triad supports designing for entangled speculation. Plotting the environments of an investigation on a triangle diagram such as the one in Figure 7.2 below can help designers assess whether their RtD activities draw on all three environments: whether the Lab is experimenting with opening potentials and early material experiments, whether the Field is grounding and situating them, and whether the Showroom is creating spaces for reflection, critique, and new forms of sharing outputs as *goods for speculating*. In this formulation, designing for entangled speculation holds the Lab, Field, and Showroom in productive conditions for inquiry.

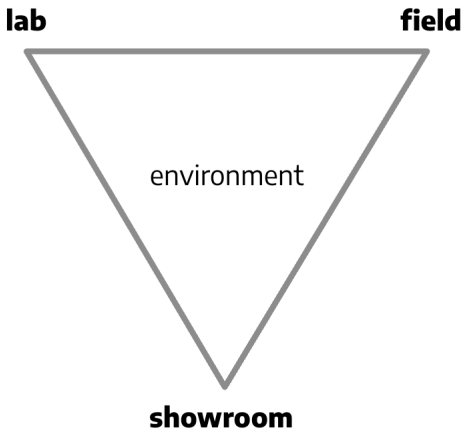

Figure 7.2. *Triangle graph for entangled lab-field-showroom environments.*

7.4 Synthesis and Transition

Reading back through the three investigations through a quantum lens has clarified that entanglement in this dissertation is not only a theoretical metaphor, but a practical orientation that reshapes how speculation in design is done. Entanglement shows up at every level, in how workshops are assembled, how participants relate to one another and the design contexts, and how stories and artifacts are produced and interpreted. It is present in the ways participants hold multiple futures at once, in the cuts they make when they decide what to notice and what to ignore, and in the difficulties of separating "context," "method," and "outcome" from each other in practice.

The diffractive reading makes visible how different aspects of quantum entanglement have been unevenly emphasized across the three projects. *Post(-)human Hazmat* leaned most heavily on interconnectedness, using posthuman storytelling and theory intensive sessions to unsettle human centered categories and binary logics. *Speculative F/Actors* foregrounded superposition and the observer effect by inviting participants to hold multiple climate futures in play and attend to how their own positions shaped what could be seen and said. *Entangled Justice* concentrated on non locality and nonlinearity, treating participants' work as already entangled with wider infrastructures and injustices, and used mapping to surface relations that move across scales and sites. Together, these investigations do not converge on a single definition of entanglement. Instead, they offer a set of speculative experiments in how entangled relations can be noticed, narrated, and re configured in collaboration with others.

In the next chapter, Discussion and Conclusion, I move outward from the three investigations and the DES framework to consider how this work contributes to broader conversations in design research and pedagogy. I situate *designing for entangled speculation* in

relation to existing research through design traditions, speculative and critical design practices, and posthuman and entanglement oriented HCI. I also reflect on what these investigations suggest for teaching and learning, including how designers might be supported in developing competencies for working with entanglement, uncertainty, and justice in their own practices. Finally, I outline directions for future work, and propose ways that DES might be taken up, challenged, and extended by others who are also working to stay with, and design within, the troubles of an entangled world.

Chapter 8: Discussion & Conclusion

An Entanglement Design Framework: Tools for Speculative Justice. *Discussion:* Introduces what the chapter will do and sets up the interpretive work to follow.

DES Framework in the Context

From this, the *Designing for Entangled Speculation* (DES) framework takes shape as a set of approaches that attune designers and researchers to develop speculative engagements for complex and wicked problems. At the same time, there are important limits to what DES is trying to do. It does not claim to be a complete or universal framework for speculation, nor a definitive translation of quantum physics into design practice. It does not provide a step by step recipe for running workshops, guaranteeing outcomes, or resolving the tensions that arise when people with different stakes and power positions come together. DES is intentionally partial and situated. It is offered as one contribution among many ongoing efforts to link entanglement, speculation, and design justice, and it remains open to revision as others test and transform it in new contexts.

This positioning also matters for how the work should be read within RtD. The framework does not close down the program of investigations. Instead, it marks a momentary consolidation in an ongoing arc, drawing together what these particular workshops, participants, and sites have made possible while acknowledging the gaps and missed opportunities identified in the analysis. In that sense, DES is both an outcome of this dissertation and an invitation to continue experimenting with entangled speculation in ways that exceed the specific projects described here. It opens space to ask how we articulate the kinds of change we hope to bring into the world, what mechanisms and practices might support such change, and how justice may take shape differently for different people, communities, and contexts.

On Speculation

Speculation is not a luxury of design—it is its very foundation. Every design decision projects into an uncertain future, reckoning with the contingencies of the present and the unknowns that lie ahead. Yet speculation is never neutral. It has long been shaped by the dominant forces of colonialism and capitalism, which determine whose futures are rendered legible, which trajectories count as progress, and which possibilities are dismissed as impractical, irrational, or impossible. To engage in speculation is therefore to work within structures that delimit the field of possibility, while also striving to unsettle and

reconfigure those structures. The question is not whether design speculates, but whose futures it makes possible and whose futures it forecloses.

Understanding speculative design through the lens of quantum mechanics offers a way to rethink these inherited assumptions. Quantum entanglement principles such as non-locality, and indeterminacy reveal a world that is not fixed or isolated, but emergent and relational. Design, too, should embrace this reality and strive for a reflexive and relational practice that recognizes how design participates in shaping the social, material, and ecological forces it engages. Rather than seeking control or certainty where there is none, this orientation frames speculative work as a process of designing with, not against, the irreducible complexity of entangled life.

At the same time, design has always been speculative. Every product, system, and interface embodies imagined futures: how it will be used, who it will serve, what values it will reinforce, and what forms of life it will sustain or suppress. Too often, these futures are constrained by inherited norms of efficiency, scalability, and optimization—the ghosts of industrial logic that continue to shape what is thinkable in contemporary design practice. The speculative turn in design is therefore not about introducing speculation where it was absent; it is about making visible the speculative conditions already at work. Once surfaced, these conditions can be interrogated, contested, and expanded.

Integrating speculative design with quantum insights acknowledges the world as it actually is: interconnected, uncertain, and deeply entangled. The wicked problems that define our moment—climate crisis, social inequity, technological disruption—refuse linear resolutions. However, as Bruno Latour has stated, "we are somewhat disoriented in space and time at the time of the ecological crisis" (Latour, 2021).[216] Such disorientation is not a failure of design but evidence of the shifting ground upon which design already operates. To work amid entangled, multiscalar crises is to accept that orientation cannot come from linear models, singular perspectives, or stable problem definitions. Instead, designers must find ways to reorient themselves within uncertainty, hold contradiction, trace relational consequences, and attend to the entangled conditions that shape what futures become possible. Therefore, reframing design speculation through quantum mechanics is not a metaphorical gesture but an ontological and epistemological one, challenging the extractive and deterministic habits of thought that have governed dominant design traditions.

[216] Latour, Bruno. 2018. *INSIDE: A lecture-performance by Bruno Latour*. YouTube video. https://www.youtube.com/watch?v=gzPROcd1MuE.

Contributions to Design Research & Pedagogy

Designing for Entangled Speculation (DES) contributes to design research and pedagogy by offering a set of orientations, practices, and environments that prepare designers to work within the complexity, uncertainty, and ethical demands of our contemporary moment. Across the investigations in this dissertation, DES emerges as a pedagogical and epistemic stance that reorients designers toward multiplicity, relationality, and justice. This orientation has implications for how we teach design, how speculative practice is theorized and enacted, how justice becomes entangled within design processes, and how future practitioners develop competencies for navigating entangled worlds.

Design Education

Traditional design pedagogy often privileges clarity, bounded problem spaces, and solution-oriented thinking, which can inadvertently narrow the imaginative and ethical scope of design practice. The DES framework counters this tendency by emphasizing inquiry over resolution, relational awareness over object-centered outputs, and experimentation across lab, field, and showroom environments. DES offers a pedagogical vocabulary and structure for teaching design in wicked contexts. Through the workshop investigations, DES demonstrates how students and practitioners can learn to trace entanglements, work with partial knowledge, and understand their own positionality in relation to the issues they seek to address. These practices cultivate forms of design literacy that are better suited to the demands of climate change, multispecies futures, and socio-technical uncertainty.

Speculative Practice

DES reframes speculative design as a mode of inquiry grounded in quantum-informed conceptions of potentiality, co-constitution, and nonlinearity. DES positions speculative practice as a competency for designers navigating entangled conditions. The four orientations (superposition, observer effect, interconnectedness, and nonlocality & nonlinearity) offer novel lenses through which speculative practice can be envisioned, enacted, and analyzed. Through these orientations, designers learn to hold multiple potential futures in play, examine how their own assumptions collapse certain trajectories, materialize relations in tangible ways, and engage across scales. DES thus contributes to speculative design by broadening its conceptual grounding and demonstrating how speculative engagement can unfold collaboratively, reflexively, and ethically.

Justice-Oriented Methods

DES situates values and injustice as entangled conditions that shape every stage of inquiry. The *Entangled Justice* workshop series shows how speculative work can draw directly from lived experience, domain knowledge, and situated expertise to surface the systemic, infrastructural, and historical forces that configure injustices. DES introduces methodological moves that foreground accountability, situatedness, and the politics of ontologies and epistemologies. These methods expand design by shifting the focus from designing "for" justice toward designing with the complexities, contradictions, and entanglements that constitute justice in practice. In doing so, DES contributes a set of methodological tools that help designers engage ethically with wicked problems.

Competencies for Entangled Futures

Finally, DES contributes to the cultivation of competencies needed for designing within entangled and rapidly emerging futures. These competencies extend beyond technical skills to include relational sensitivity, multi-scalar reasoning, speculative reflexivity, and the ability to navigate uncertainty without collapsing it prematurely. Through the iterative cycles of the investigations, DES demonstrates how designers can learn to inhabit ambiguity, identify and question their own assumptions, trace how decisions reverberate across contexts, and remain accountable to the more-than-human worlds implicated in design action. By framing these competencies as emergent rather than prescriptive, DES supports an ongoing practice of attunement. These are not competencies for mastering complexity, but for staying with it, shaping forms of design practice attuned to the ethical, ecological, and political realities of the future.

A critical aspect of this reflexive competency involves recognizing that interpretive work itself entails moments of collapse. While this dissertation foregrounds how participants encounter and enact collapse through speculative engagement, my own analytic process also required a series of interpretive cuts. Decisions about how to code the data, how to interpret participant reflections, which quantum concepts to foreground in a given investigation, and whether an activity functioned more as Lab, Field, or Showroom practice all narrowed multiple possible readings into provisional accounts. Making these cuts visible positions analysis as an entangled and situated practice rather than a neutral act of classification. Importantly, the DES framework is not intended only to help designers surface participants' assumptions and decision points, but also to support designers in recognizing their own interpretive cuts, values, and commitments as they move between facilitation, analysis, and theory building.

Recognizing interpretive cuts as moments of collapse does not imply that such decisions should be avoided or endlessly deferred. In practice, entangled and wicked problems

demand moments of decisiveness, even when knowledge is partial and consequences are uncertain. To refuse to make a cut is itself a choice that carries ethical and material implications. From this perspective, responsible design practice involves making cuts deliberately, with awareness of their situatedness and potential effects. The DES framework therefore does not encourage designers to remain indefinitely in superposition, but to cultivate the capacity to act while staying accountable to what their decisions bring into focus and what they leave aside.

Limitations

This dissertation emerges from a particular constellation of sites, collaborators, and commitments, and the insights developed through the three investigations reflect those situated conditions. The workshops were facilitated in environments already receptive to experimentation and speculative inquiry, which likely shaped both the dynamics of participation and the kinds of possibilities that could surface.

My role as designer–researcher also introduced interpretive influence, as the framing, materials, and facilitation strategies reflected my own methodological and ethical orientations and interests. This dissertation focuses on participants' experiences and sensemaking through the engagement with the workshop activities and prompts rather than on close analysis of the material artifacts produced in the workshops, a scope decision that leaves detailed material readings to future work. In addition, I am not a trained physicist, but I am inspired by the productive power of the weird, and few accounts of ontological reality are stranger or more generative than those offered by quantum physics. While quantum concepts informed the development of the DES framework, they were engaged as conceptual provocations rather than scientific explanations, and readers from other disciplines may interpret this translation differently.

Because facilitation and framing play such a central role in shaping these workshops, there is a risk that speculative and entanglement-informed workshops can backfire if they are poorly facilitated or experienced as imposed, abstract, or disconnected from participants' realities. In such cases, participants may disengage not only from a particular workshop, but from speculative or justice-oriented approaches more broadly, making it harder to re-engage them in future conversations about complexity, responsibility, or care. This risk is especially salient in educational settings where participation is required rather than voluntary. Attending carefully to facilitation style, participant readiness, and how speculative work is introduced and supported is therefore critical, and potential unintended consequences should be actively monitored as these approaches are adapted to new contexts.

Finally, the temporal boundaries of dissertation work limited opportunities for long-term engagement, making it difficult to assess how speculative practices might continue to transform or take root beyond the immediate workshop contexts. These constraints mark the work as partial and situated, while also pointing toward opportunities for future research to extend, challenge, and adapt these approaches in new settings. See the Limitations section in the Introduction for more details of these limitations.

Future Work

The work of *designing for entangled speculation* continues to unfold, and there are several future directions to explore. One path involves developing a "Nature–Culture Nomenclature" project to explore how ontological structures shift and maintain notions of separability. This project would bring together perspectives from critical race theory, feminist and queer studies, disability justice, and multispecies ethics and trace how different traditions articulate categorical difference, relation, and responsibility.

Another direction involves applying the DES framework into new domains. I see possibilities in policy spaces, environmental planning, community organizing, and other contexts where the stakes of entanglement are already felt but rarely named. Extending DES in this way requires attending to how practices change as they meet new publics, infrastructures, and forms of expertise. It also requires acknowledging that what works in one setting may become something different in another. By adapting and testing these orientations across domains, I aim to understand how entangled speculation becomes a situated practice that takes shape with and through the conditions it encounters.

Finally, I see potential in bringing DES directly into the classroom as a scaffold for teaching and pedagogy design. Using the orientations as a pedagogical structure to help students learn to work with uncertainty, trace entanglements, and understand their own positionality in relation to complex issues. In this setting, DES becomes a guide for cultivating competencies, relational reasoning, and speculative reflexivity that support more attuned and accountable forms of design learning.

Collectively, these directions position DES as an emerging practice. Future work will continue to test, revise, and reimagine what designing for entangled speculation can do as it moves across new contexts, publics, and concerns. In this ongoing movement, DES remains committed to cultivating more attuned, imaginative, and accountable ways of living and designing within an entangled world.

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