Chapter 3:
THEORETICAL FRAMEWORK

The ethnography presented in this text draws on two main areas of study – STS and anthropology – complemented by a design-informed perspective. The combination of the two fields enables an empirical examination of the practices of preparing, collecting, and producing knowledge in the field sciences. It provides the theoretical framework for empirical and sensory practices, the role of embodiment and skill, and the social and institutional conditions of scientific knowledge production. Against the background of design, the combination of these fields allows technology to be considered, with special consideration of their cognitive, epistemic, and methodological agencies.

I highlight all the practices in which the biologists in my case study engage, from data collection to publication, thereby drawing on the commonalities between ethnographic accounts and the work of field biology, which are 'quite similar' given that they 'involve[s] watching and describing the social relations the analyst finds',[1] and share certain

1
Anna Tsing, 'When the Things We Study Respond to Each Other: Tools for Unpacking "the Material"', in *Anthropos and the Material,* ed. Penny Harvey, Christian Krohn-Hansen, and Knut G. Nustad (Duke University Press, 2019), 228.

historical commonalities. By creating these relationships, I extend anthropological scholarship to the sciences and vice versa, thus productively blurring the boundaries, as I believe that it is in these boundaries that the unknown can be found. With this, I seek to contribute a fresh perspective on what it means to produce scientific knowledge, as a practice that appreciates that it is 'earthbound'[2] and 'situated'.[3] The goal is to ethnographically focus on the onto-epistemologies[4] of science-in-the-making as sensory, situated, and mediated practices in which the knowing subject and the object of knowledge production 'intra-actively'[5] become entangled. This chapter provides further detail on these key theoretical frameworks, their commonalities, and key concepts that are then interwoven throughout successive chapters. But first, let us consider the context and rationale for the theoretical framework adopted in this work.

Context and Rationale

Over the past few decades, advances in molecular and nanoscience – and the scientific observations they have enabled – have drawn increasing attention from scholars in the sciences, technology studies, and the history and philosophy

2
Bruno Latour, *Down to Earth: Politics in the New Climatic Regime* (Cambridge, UK: Polity, 2018).

3
Haraway, 'Situated Knowledges'.

4
'[...] knowing is a material practice of engagement as part of the world in its differential becoming intra-acting' (Barad, *Meeting the Universe Halfway,* 89). Thus, epistemologies and ontologies are inseparable. Barad would add ethics to intra-dependency of the concepts, as represented in this neologism.

5
Barad, *Meeting the Universe Halfway*.

of science.[6] Numerous studies have been published on subjects such as CERN (The European Organization for Nuclear Research) and nanoscale image production. However, the excitement about these scientific achievements has overshadowed interest in the field sciences, such as evolutionary biology or ecology, which have received little attention.[7]

However, with the alarming consequences of climate change becoming increasingly visible in recent years, the relationship between human beings and nature has been questioned anew, and, as a result, the role of the sciences has shifted.[8] We currently face the sixth mass extinction, through irreversible change to ecosystems and the permanent loss of flora and fauna, which has returned the public's attention to the natural world. With this development, scientific attention has also returned to evolutionary biology.

6
See, e.g., Barad, *Meeting the Universe Halfway;* Anne Dippel, 'The Big Data Game: On the Ludic Constitution of the Collaborative Production of Knowledge in High-Energy Physics at CERN', *Naturwissenschaften, Technik und Medizin* 25, no. 4 (2017): 485–517; Judith Dobler, 'Collaborative Imaging: The Communicative Practice of Hand Sketching in Experimental Physics', in *Proceedings of DRS 2016: Future-Focused Thinking, Vol. 3, Sec. 5 Aesthetics, Cosmopolitics and Design* (Design Research Society, 2016), 997–1011; Judith Dobler, 'Drawing Together: Collaborative Design Practices in Experimental Physics', in *Nordes: Design+Power* (Nordes, 2017); Hoffmann and Wittmann, 'Introduction: Knowledge in the Making: Drawing and Writing as Research Techniques'; K. Knorr-Cetina, *Epistemic Cultures: How the Sciences Make Knowledge* (Cambridge, MA: Harvard University Press, 1999); Bruno Latour and Steve Woolgar, *Laboratory Life: The Construction of Scientific Facts,* ed. Jonas Salk (Princeton, NJ: Princeton University Press, 1979); Merz and Hinterwaldner, 'Neue Bilder, Modelle und Simulationen: Zwischen Repräsentativität und Produktivität'; Hans-Jörg Rheinberger, *Toward a History of Epistemic Things: Synthesizing Proteins in the Test Tube* (Stanford, CA: Stanford University Press, 1997), 325.

7
See, e.g., Michael G. Hadfield and Donna J. Haraway, 'The Tree Snail Manifesto', *Current Anthropology* 60, no. 20 (2019): S209–35; Latour, 'The "Topofil" of Boa Vista: A Photo-Philosophical Montage'.

8
Adam Frank, Marcelo Gleiser, and Evan Thompson, *The Blind Spot: Why Science Cannot Ignore Human Experience* (Cambridge, MA: The MIT Press, 2024).

Against this background, philosophical discourse on nature, ecology, and evolution has received increasing attention.[9] Moreover, in anthropology, nature and its entanglements with the social and the political realm have become the subject of recent scholarly interest.[10] What remains missing from the literature is an STS perspective that both philosophically and culturally situates ecology within the discourse and examines the practices of knowledge production that shape current philosophical and anthropological discourse.

Introduction to Key Concepts

The primary theoretical framework of this text draws on the feminist concept of objectivity and the conditions under which scientific knowledge is produced. Two of the most important concepts in this research are Haraway's situated

9
See, e.g., Emanuele Coccia, *The Life of Plants: A Metaphysics of Mixture* (Cambridge: Polity, 2019); Vinciane Despret, *What Would Animals Say If We Asked the Right Questions?* (Minneapolis: University of Minnesota Press, 2016); Michael Marder, 'For a Phytocentrism to Come', *Environmental Philosophy* 11, no. 2 (2014): 237–52, https://doi.org/10.5840/envirophil20145110; Michael Marder, *Plant-Thinking: A Philosophy of Vegetal Life* (New York: Columbia University Press, 2013); Timothy Morton, *Dark Ecology: For a Logic of Future Coexistence* (New York: Columbia University Press, 2016); Merlin Sheldrake, *Entangled Life: How Fungi Make Our Worlds, Change Our Minds, and Shape Our Futures* (London: The Bodley Head, 2020); Thom Van Dooren, *Flight Ways: Life and Loss at the Edge of Extinction,* Critical Perspectives on Animals: Theory, Culture, Science, and Law (New York: Columbia University Press, 2016).

10
See, e.g., Wendy Harding, 'Anna Tsing, Heather Swanson, Elaine Gan, Nils Bubandt (Eds.), Arts of Living on a Damaged Planet: Ghosts and Monsters of the Anthropocene', *Miranda,* no. 16 (2018): 0–5, https://doi.org/10.4000/miranda.11648; Robin Wall Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge and the Teachings of Plants*. Minneapolis: Milkweed Editions, 2013; Eduardo Kohn, *How Forests Think: Toward an Anthropology Beyond the Human* (Los Angeles: University of California Press, 2013); Anna Lowenhaupt Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* (Princeton: Princeton University Press, 2015); Rachel Mundy, 'Birdsong and the Image of Evolution', *Society and Animals* 17, no. 3 (2009): 206–23, https://doi.org/10.1163/156853009X445389; Andrew Whitehouse, 'Listening to Birds in the Anthropocene: The Anxious Semiotics of Sound in a Human-Dominated World', *Environmental Humanities* 6 (2015): 53–71.

knowledges[11] and physicist and philosopher Karen Barad's concepts of agential realism, such as intra-activity and onto-epistemologies.[12]

Regarding the role of visual skill in scientific practices of worldmaking, I refer to anthropologist Cristina Grasseni's theories of skilled visions and skilled mediations.[13] I attempt to relate them to what skill may mean in terms of situatedness, embodiment, and sensory practices as part of the apparatus of knowledge production, extending them to what I call *situated mediations*.

Additional concepts woven throughout the monograph are circulating reference and immutable mobiles,[14] as formulated by Latour, based on one of the few STS studies in the field sciences. Together with pedologists in Boa Vista in the Amazon rainforest, he studied how scientists *translate* their research subject, the soil of the rainforest, into their laboratories across the world, and how they develop papers based on these data.[15]

While Latour speaks of cascades of inscriptions, transformation, transfers, and translational steps, I prefer the concept of filtering to discuss what is filtered out, lost, and left behind, as well as what is gained through these steps of transformation in the research process.

11
Haraway, 'Situated Knowledges'.
12
Barad, *Meeting the Universe Halfway*.
13
Cristina Grasseni, 'Skilled Vision: An Apprenticeship in Breeding Aesthetics', *Social Anthropology* 12, no. 1 (2004): 41–55; Cristina Grasseni 'Skilled Visions: Toward an Ecology of Visual Inscriptions', in *Made to Be Seen: Perspectives on the History of Visual Anthropology,* ed. Marcus Banks and Jay Ruby (Chicago: University of Chicago Press, 2007), 19–44; Cristina Grasseni *Skilled Visions: Between Apprenticeship and Standards,* ed. Christina Grasseni (New York, Oxford: Berghahn Books, 2009); Cristina Grasseni, 'Beauty as Skill and "Common Sensing"', in *Anthropology and Beauty: From Aesthetics to Creativity,* ed. Stephanie Bunn (London: Routledge, Taylor & Francis Group, 2018); Cristina Grasseni and Thorsten Gieser, 'Introduction: Skilled Mediations', *Social Anthropology* 27, no. 1 (2019): 6–16.
14
Latour, 'The More Manipulations the Better'; Latour and Woolgar, *Laboratory Life*.
15
Latour, 'The "Topofil" of Boa Vista: A Photo-Philosophical Montage'.

Objectivity

In their monograph *Objectivity*, Lorraine Daston and Peter Galison[16] connect approaches from the history of science to the history of art by relating visualisation practice to knowledge production. To them, the construction of objectivity is intertwined with the subjectivity of the researchers[17] and the 'moralization of objectivity'.[18] From their perspective, the researching subjects must first familiarise themselves with the practices of scientific work; in this sense, it is also a matter of belonging to a thought collective.

Daston and Galison describe this history of objectivity in relation to image production in the sciences, showing how it is shaped by historical developments. In this context, they emphasise the 'diversity and contingency of the components that make up the current concept of objectivity'.[19] By studying the historical development of scientific images, the authors claim that it was not technological development alone that shaped these images, but rather the prevailing zeitgeist and virtues associated with each era. Thus, they focus instead on the subjectification practices required by researchers to produce objective images.

This perspective also allows the authors to take institutional, political, and scientific developments into account and assess how they affect authorship and the production of evidence in their visual representation. This subjectification is the result of the scientists' attunement to a certain style, and to rules, modes, and practices as a prerequisite for scientific image production.

16
Daston and Galison, *Objectivity*.
17
Daston and Galison, 'The Image of Objectivity', 82.
18
Ibid.
19
Ibid.

Achieving objectivity in this sense is entangled with the so-called 'epistemic virtues'.[20] These virtues, namely 'truth to nature',[21] 'mechanical objectivity',[22] and 'trained judgement',[23] subjectivise the scientists by means of visual practices in such a way that the resulting images are considered objective. In addition to this, Daston and Galison develop three ideal personas for scientists:

> The sage, whose well-stocked memory synthesizes a lifetime of experience with skeletons or crystals or seashells into the type of that class of objects; the indefatigable worker, whose strong will turns inward on itself to subdue the self into a passively registering machine; the intuitive expert, who depends on unconscious judgment to organize experience into patterns in the very act of perception.[24]

Daston and Galison's contribution helps to transform the concept of objectivity into one of subjectivity, overcoming the predominant notion of a neutral observer, similar to a god's view from nowhere, as suggested by Haraway. I combine this with Barad's perspective on science as an intra-active entanglement between knowing subjects and objects of knowledge production. These co-constitute each other intra-actively in scientific practices, thus forming apparatuses. This perspective allows one to address the subject–object dichotomy in conventional science production and question the apparent separation of the two. Objectivity, in particular, as the term itself suggests, creates a subject–object divide between the researching subject, that is, the evolutionary biologist and the object of research, the Siberian jays.

20
Daston and Galison, *Objectivity,* 39.
21
Ibid., 55.
22
Ibid., 115.
23
Ibid., 309.
24
Ibid., 44.

While a subject–object divide can be observed in scientific knowledge production, a separation between humans and non-humans is also at stake. During fieldwork, I observed biologists becoming birds, aligning with the environment, engaging with the birds and forest on a sensory level, and even addressing the birds by imitating bird sounds, thus attempting to meet them on equal terms. The biologists entered the field as human beings, but during fieldwork they increasingly aligned their movements, behaviours, and even their thinking with that of the birds. Therefore, fieldwork is highly shaped by complex sensory engagement and multimodal social processes, and does not allow one to maintain these dualities. Accordingly, while an ontological separation of nature and culture still occurs in the publication of scientific information in the natural sciences, these ontologies collapse during the production process, and human and non-human lifeworlds overlap as naturecultures,[25] challenging the dominant *great divides*.

Situated Knowledges

Haraway developed the concept of situated knowledges in collaboration with other feminist scholars, including Sarah Harding, Nancy Hartsock, and Karen Barad, famously coining the term in her 1988 essay, *Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective*. In this paper she suggested a feminist rereading of the, often problematic, notion of objectivity. Situated knowledges help to overcome the objectivity–relativism duality. While objectivity suggests neutrality, universality, and impartiality, relativism renders knowledge a question of opinion, 'a way of being nowhere while claiming to be everywhere equally'.[26] In Haraway's words: 'The moral

25
Donna Haraway, *When Species Meet* (Minneapolis: University of Minnesota Press, 2008).
26
Haraway, 'Situated Knowledges', 584.

is simple: only partial perspective promises objective vision'.[27] Therefore, it is not so much about doing away with objectivity but reconceptualising it.

Haraway employs situated knowledges as a concept that preserves claims to objectivity but reveals the partiality of each perspective. She considers the possibility of theories for the *real* world, based on 'strong truth claims' (Young, 2022) that are not solely socially constructed and contingent. Thus, situated knowledge makes the political, institutional, epistemological, ethical, and ontological circumstances of knowledge production visible, situating it within the power relations that enable them. Feminist situated knowledge considers the diverse material-semiotic agencies involved in the production of knowledge. They can be understood as active instruments that produce knowledge, an apparatus of bodily production creating 'material-discursive entanglements' in which epistemologies and ontologies become interlaced as onto-epistemologies.[28]

Situated knowledges are a 'view from somewhere'[29] as opposed to the 'god trick', which is a 'gaze from nowhere', an 'immaterial gaze', and an impartial perspective that has the capacity 'to represent while escaping representation'.[30] Yet the 'power to see', to actively organise the world, is shaped by 'semiotic-material'[31] conditions that are far from self-evident. They are technologically, socially, and psychologically learnt.

Haraway continues with reference to technologies that work based on vision, a metaphor that is widely used in feminist science studies as vision that is characterised by distance rather than entanglement. Ecofeminists, in particular,

27
Ibid., 583.
28
Barad, *Meeting the Universe Halfway*.
29
Haraway, 'Situated Knowledges', 590.
30
Ibid., 581.
31
Ibid., 585.

aim to deconstruct this notion of vision as objective owing to its distance, emphasising instead that *seeing* in science is an embodied practice shaped through apparatuses, manipulations, and bodily engagement. It is also a matter of touching and, thus, not sensory engagement from a distance but based on proximity:

> The 'eyes' made available in modern technological sciences shatter any idea of passive vision; these prosthetic devices show us that all eyes, including our own organic ones, are active perceptual systems, building on translations and specific ways of seeing, that is, ways of life. There is no unmediated photograph or passive camera obscura in scientific accounts of bodies and machines; there are only highly specific visual possibilities, each with a wonderfully detailed, active, partial way of organizing worlds.[32]

Vision, as Haraway describes it, is not a neutral and objective activity performed by the eye; instead, it is skilled, trained, and active. Guided and directed by the viewer's position and situatedness within the world, it is also based on disciplinary education, knowledge, skill, and interest: it is skilled vision. In relation to scientific research, it is not a 'view from above, from nowhere, from simplicity', but rather a 'view from the body',[33] which is situated, partial, and thus not universal.

Skilled Visions / Skilled Mediations

Vision, 'a semiotic eye',[34] is not merely looking; it is intertwined with an 'apprenticeship of the eye'[35] – a process of training and knowledge in the employment of this bodily tech-

32
Ibid., 583.
33
Ibid., 589.
34
Grasseni, 'Conference on Neuroesthetics'.
35
Grasseni, 'Skilled Vision: An Apprenticeship in Breeding Aesthetics', 42.

nique. Skilled visions are 'invisible, embodied, sensorial, tacit, a result of incogation, training and acculturation'[36] as well as a 'complex relation between attention, habit, and representational capacities'.[37] Skilled visions can be described as a professional visual competence based on the biologists knowing what to look for and how to look at it when doing fieldwork or analysing scientific images. Thus, biologists mediate between the thought collective and the object of interest.

Cristina Grasseni and Thorsten Gieser developed the concept of skilled mediations as a response to the sensory turn in the social sciences, considering vision as a result of bodily and sensory practice, apprenticeship, and skill, which often occur in combination with technologies. Thus, they extended Grasseni's 'skilled visions'.[38] These authors aim 'to advance the epistemological understanding within anthropology of mediation, a concept indicating the technical and sensory apprenticeship that is intrinsic to enskillment – a process that we identify as crucial to ethnographic practice and anthropological understandings'.[39]

While skilled visions lacked the role of mediation through 'focusing media', with skilled mediations the authors focus on 'how fieldwork experience is itself crucially mediated by tools, educated attention and relevant media'.[40] Thus, skilled mediation is culturally determined and produced by 'situated learning',[41] which defines how the world is studied. Mediation is also always a question of the thought

36
Grasseni, 'Conference on Neuroesthetics'.
37
Grasseni, 'Beauty as Skill and "Common Sensing"', 224.
38
Grasseni, 'Skilled Vision: An Apprenticeship in Breeding Aesthetics'; Grasseni, 'Skilled Visions: Toward an Ecology of Visual Inscriptions'; Grasseni, 'Conference on Neuroesthetics'.
39
Grasseni and Gieser, 'Introduction: Skilled Mediations', 7.
40
Ibid., 7.
41
Ibid., 8.

collective, which defines a certain perspective that is shaped by discourse. It is informed by a thought style and is a question of bodily production.

Situated knowledge should be viewed in conjunction with skilled mediations because it allows for an expansion of Gieser and Grasseni's concept through its onto-epistemological account as material-discursive practices of bodily production, which are also always situated. This allows for emphasis on the entanglements between vision and the senses, and the technologies, epistemologies, and ontologies of visual and sensory attunement. Therefore, I consider skilled mediations part of situated mediations.

Representations are produced based on cultural and bodily techniques.[42] From these perspectives, social anthropologists contribute an additional analytical framework to the role of image production as a method with epistemological value. Here, the discussion of 'anthropology as a form of image-making practice'[43] is widespread regarding 'ways of knowing, skilled practice, improvisation and the imagination',[44] as well as 'tacit'[45] and 'embodied knowledge'.[46] With regard to embodied knowledge, Ingold[47] and Taussig's[48] theories of drawing have provided intensive reflection on 'its significance as a special kind of knowledge practice'[49]

42
Marcel Mauss, 'Techniques of the Body', in *Journal de Psychologie Normal et Patholigique,* ed. Marcel Mauss (London: Routledge, 1935), 271–93; Harun Maye, 'Was Ist Eine Kulturtechnik?', *Zeitschrift Für Medien und Kulturforschung,* no. Heft 1 (2010): 121–35.

43
Grimshaw and Ravetz, 'Drawing with a Camera?', 255.

44
Ibid., 215.

45
Michael Polanyi and Amartya Sen, *The Tacit Dimension* (Chicago: University of Chicago Press, 2006).

46
Causey, *Drawn to See;* Tim Ingold, *Lines – A Brief History* (New York: Routledge, 2007); Almut-Barbara Renger et al., 'Körperwissen: Transfer und Innovation', *Paragrana* 25, no. 1 (2016): 13–19.

47
Ingold *Lines – A Brief History;* Tim Ingold, *Making: Anthropology, Archaeology, Art and Architecture* (New York: Routledge, 2013); Tim Ingold, *The Life of Lines* (New York: Routledge, 2015).

48
Taussig, 'What Do Drawings Want?'; Taussig, *I Swear I Saw This.*

49
Grimshaw and Ravetz, 'Drawing with a Camera?', 255.

and an analysis of the interfaces between drafting and thinking. Thus, these accounts allow for a better understanding of how drafting practices influence sensory engagement with the environment.

Immutable Mobiles

Scientific knowledge production, like the production of objectivity, is always the result of researchers' practical engagement with their epistemic object.[50] Steve Woolgar and Bruno Latour[51] expand on the role of practices within the sciences in their laboratory studies. They focused on the 'social construction of scientific facts', which is also the subtitle of their 1979 published work, thereby adopting a social constructivist perspective that assumes that scientific work is possible only through a network of (also social) practices that extend beyond the scientific process. They focus particularly on the process of writing and the importance of the result – the scientific paper constructed through writing practices including transcriptions, inscriptions, and translations.

These steps can also be applied to visual practices and scientific image production, and can be understood as 'chains of transformation'[52] or 'a regulated series of transformations, transmutations, and translations'[53] based on inscriptions. Inscriptions are 'a small window through which one could read a very few signs from a rather poor repertoire (diagrams, blots, bands, columns)'.[54] Thus, these materials result from scientific operations performed on material carriers, such as notebooks. Latour continues: 'All these

50
Rheinberger, *Toward a History of Epistemic Things*.
51
Latour and Woolgar, *Laboratory Life*.
52
Latour, 'The "Topofil" of Boa Vista: A Photo-Philosophical Montage', 70.
53
Ibid., 58.
54
Latour and Woolgar, *Laboratory Life*, 4.

inscriptions, as I called them, [are] combinable, superimposable and could, with only a minimum of cleaning up, be integrated as figures in the text of the articles people were writing'.[55] They work as circulating references that keep the scientific process steady.

Scientific certainty can be produced only through these chains of signs that, according to these questions, become stronger over the course of their referential production, with one sign leading to the next to return them to the discourse[56] or, rather, turn them into scientific objects. Signs, then, result from the translation processes by means of representational practices that must be kept steady as references but also mobile, as they circulate simultaneously. Throughout this book, I attend to the translational practices that these signs undergo, from reference to the bird to representation in publication, discussing them as filters.

Adopting this perspective allows one to draw attention to the agency of signs, such as references produced through representational practices that enable consistency in data collection. In this regard, researchers have studied the correlation between visual and material practices in scientific processes, and the associated translation steps that lead from the researched object to a scientific fact.[57]

The final section of this chapter considers design research and the perspectives it offers in a transdisciplinary study such as the present one.

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Ibid.

56
Bruno Latour, 'Circulating Reference: Sampling the Soil in the Amazon Forest', in *Pandora's Hope: Essays on the Reality of Science Studies* (Cambridge, MA: Harvard University Press, 1999), 32.

57
See, e.g., Stephan Kammer et al., *Spuren Erzeugen. Zeichnen und Schreiben als Verfahren der Selbstaufzeichnung,* ed. Barbara Wittmann (Zürich/Berlin: diaphanes, 2009); Knorr-Cetina, *Epistemic Cultures;* Krauthausen et al., *Notieren, Skizzieren. Schreiben und Zeichnen als Verfahren des Entwurfs;* Bruno Latour, 'Drawing Things Together. Die Macht der Unveränderlich Mobilen Elemente', in *ANThology: Ein Einführendes Handbuch Zur Akteur-Netzwerk-Theorie,* ed. Andréa Belliger and David J. Krieger (Zürich/Berlin: transcript Verlag, 2006), 259–307; Merz and Hinterwaldner, 'Neue Bilder, Modelle und Simulationen: Zwischen Repräsentativität und Produktivität'.

Design Research

Following the STS example of primarily adopting the natural sciences as objects of social scientific analysis, design research uses the natural sciences to address questions about the epistemologies of design. The approach provides new perspectives on the practices of scientific work, from data collection in the field to the production of scientific papers. Since the design methods movement of the 1960s, design researchers have been working on definitions and conceptualisations of design methods and processes, with special regard to their cognitive-epistemic and communicative-interactive role.[58] These researchers pursue the goal of establishing design as an independent academic field and exploring the transdisciplinary interfaces between design and knowledge.[59]

Within this context, drafting a design is understood as a human activity[60] and a problem-solving endeavour.[61] Thus, design is based on embodied and experiential knowledge and unconscious, implicit decisions. For this reason, it permeates all areas of life, including science. Nonetheless, design researchers Claudia Mareis and Christof Windgätter stated that 'the styles of thought, action and publication prevalent in the scientific world hardly developed a

58
See, e.g., Nigel Cross, 'Design Research: A Disciplined Conversation', *Design Issues* 15, no. 2 (1999): 5–10; Nigel Cross, 'Designerly Ways of Knowing: Design Discipline Versus Design Science', *Design Issues* 17, no. 3 (2001): 49–55, https://doi.org/10.1162/074793601750357196; Christopher Frayling, 'Research in Art and Design', *Royal College of Art Research Papers* 1, no. 1 (1993): 1–5; Donald A. Schön, *The Reflective Practitioner: How Professionals Think in Action,* ed. Donald A. Schön (New York: Basic Books, 1983); Herbert A. Simon, *The Sciences of the Artificial,* ed. Herbert A. Simon, vol. 33 (Cambridge, MA: MIT Press, 1997).

59
See, e.g., Claudia Mareis, *Design als Wissenskultur: Interferenzen zwischen Design-und Wissensdiskursen seit 1960* (Bielefeld: Transcript, 2011); Claudia Mareis et al., *Wild Thing. Unordentliche Prozesse in Design und Wissenschaft,* ed. Claudia Mareis and Christof Windgätter (Berlin: Kulturverlag Kadmos, 2019).

60
Hans Kaspar Hugentobler et al., *Designwissenschaft und Designforschung: Ein Einführender Überblick* (Luzern: Hochschule Luzern, 2010), 11.

61
Annette Diefenthaler, 'Problemsolving', in *Design Dictionary. Perspectives on Design Terminology,* ed. Michael Erlhoff and Tim Marshall (Basel: Birkhäuser, 2007), 307.

relationship to design themes'.[62] They add, 'There is still a hierarchical-chronological difference [...] between the actual generation of knowledge and its subsequent presentation'.[63] In other words, even though scientific research is always associated with questions of design, this interface has mostly been disregarded.

Therefore, the relationship between the production of knowledge and representational activities during research calls for a renegotiation of the boundaries between design and science. Judith Dobler's PhD project *Drawing Together*[64] is, to the author's knowledge, the only known example of an interface that addresses both design practices, such as drawing techniques and forms of knowledge, media practices, and collaborative activities. Dobler's ongoing empirical study at the University of Potsdam focuses on physicists and their drawing processes, thereby also addressing the epistemological gap by introducing the field of STS, ethnography, and design to the discourse.

In the substantive data chapters that follow, the practices of preparing (Chapter 4), collecting (Chapter 5), and producing (Chapter 6) knowledge will be described in detail and used to elucidate the hidden processes and epistemological gaps in the evolutionary biology case study.

62
Cf. Mareis et al., *Wild Thing. Unordentliche Prozesse in Design und Wissenschaft,* 10.
63
Ibid.
64
Judith Dobler, '"Flatten the Curve". The Performative Embodiment of Image, Speech, and Gestures in Scientific Communication from a Design Research Perspective', in NERD – New Experimental Research in Design 2 (Basel: Birkhäuser, 2021), 24–35, https://www.degruyterbrill.com/document/doi/10.1515/9783035623666-003/html; Judith Dobler, 'Collaborative Drawing as Knowledge Practice', in Approaches to Drawing in Architectural and Urban Design, ed. F. Colonnese, N. Grancho, and R. Schaeverbeke (Newcastle upon Tyne: Cambridge Scholars Publishing, 2024), 489–504.