THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

The unseen in between

Unpacking, designing and evaluating sustainability-oriented labs in real-world contexts

GAVIN MCCRORY

Division Physical Resource Theory

Department of Space, Earth and Environment

CHALMERS UNIVERSITY OF TECHNOLOGY

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Abstract

We live in a time of compounding ecological and social change. Given the uncertain and urgent nature of ongoing transformations, contemporary forms of governance are experiencing a central tension. The tension between controlling the present and nurturing collective capacities to enact transformative change. Amidst a wave of interest in transitions and transformations in-the-making, labs in real-world contexts have entered the discussion. Labs have emerged as appealing, novel and highly complex entities that situate and localize engagement around complex sustainability challenges. Labs carry a systemic view of change; they comprise alternative and experimental approaches; they carry a normative assumption that research has plural roles; and they hold an explicit learning orientation that infuses knowledge with action.

Given the unfolding of labs in the real world, my involvement in their design, and ongoing interests in treating both meanings and processes of sustainability, this thesis is organized around a curiosity. Its overarching aim is to *investigate how sustainability-oriented labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformations.* Underlaboured by a critical realist philosophy of science, this thesis investigates sustainability-oriented labs by way of a qualitative-dominant, case-based research strategy. It does this across three overlapping research phases, culminating in four appended papers.

In research phase one, we adopt a systematic review of sustainability-oriented labs in real-world contexts, exploring and classifying a global sample of labs according to their engagement with sustainability. In paper I, we identify and unpack 53 sustainability-oriented labs in real-world contexts. Through a mixed-methods analysis, we explore the distribution and diversity of these labs, discerning the research communities which conceptualize labs and the dimensions of their practice. In Paper III, we present an empirically grounded typology, arriving at six different types of sustainability-oriented labs: *1) Fix and control, 2) (Re-)Design and optimize, 3) Make and relate, 4) Educate and engage, 5) Empower and govern and 6) Explore and shape*.

In research phase two, paper II presents a qualitative case-based inquiry into Challenge Lab (C-Lab), a challenge-driven learning environment. Paper II conceptualizes challenge framing as embedded within an open-ended learning process, both on a level of practice and space. Experiences related to framing in C-Lab shed light on how students situate themselves and see their role within existing challenges, how they navigate limits to knowledge in complex systems, and how they self-assess their own sense of comfort and progress. In addition, we introduce three dilemmas that are not owned by teachers or students but emerge, as contradiction, within the learning space.

In research phase three, paper IV presents a multi-case comparison of evaluation practices in various sustainability transition initiatives. We conceptualize and compare the role of evaluation as a tool that can enhance the transformative capacity of sustainability-oriented labs and its broader family of transition experiments.

This thesis and its appended papers provide practical-experiential, empirical-conceptual and methodological contributions on the topic of sustainability-oriented labs in real-world contexts. In addition, it contains a layered account of an undisciplinary doctoral journey. I do this by (1) reflecting upon each research phase, (2) providing transparent accounts of positionality in relation to my research, (3) conceptualizing and reflecting upon undisciplinarity as a process of becoming, and (4) providing a mobile autoethnographic account of staying on the ground as part of a broader commitment to interrogate knowledge practices. Moving forward, I find myself motivated by three convictions: (1) *transformations are needed, and labs are invitations in between dualisms*, (2) *invitations hold the possibility of flipping big assumptions and ethical practices*, and (3) *transformations presuppose fundamental change from within both research and education knowledge systems.* They hinge upon the questioning of what both *are*, who they *are for*, and what they might need *to become*. *In conclusion, they compel us to think big, start small, and act now.*

Keywords: Sustainability transitions, sustainability transformations, laboratories, systematic review, reflexive governance, undisciplinarity, learning, education, evaluation, sustainability

List of appended papers

This thesis is based on the work contained in the following papers:

I **McCrory, G.,** Schäpke, N., Holmén, J., & Holmberg, J. (2020). Sustainability-oriented labs in real-world contexts: An exploratory review. *Journal of Cleaner Production,* 123202

Author contributions: All authors contributed to the overall conceptualisation (RQs, aims, problem statement) and methodological setup of the study. I was primarily responsible for the organization of research design and collaboration, curation of data, manuscript writing and coordinating contributions across all co-authors. NS, JH[1] & JH[2] contributed to data analysis. NS, JH[1] & JH[2] provided comments and feedback in the drafting and finalization of the manuscript. NS & JH[1] drafted sections of the paper.

II **McCrory, G.,** Holmén, J., Holmberg, J., & Adawi, T. (2021). Learning to frame complex sustainability challenges in place: explorations into a transdisciplinary 'Challenge Lab' curriculum. *Frontiers in Sustainability*, 2, 63.

Author contributions: All authors jointly conceived of and designed the study. GM and JHolmé jointly organized and analyzed the data, with support from JHolmb and TA. GM and JHolmé jointly drafted and redrafted all sections of the manuscript, with support from JHolmb and TA.

III **McCrory, G.,** Holmén, J., Schäpke, N., & Holmberg, J. (2022). Sustainability-oriented labs in transitions: An empirically grounded typology. *Environmental Innovation and Societal Transitions*, *43*, 99-117.

Author contributions: All authors contributed to the conceptualisation (RQs, aims, problem statement) and methodological setup of the study. I was responsible for the organization of research design and collaboration, for the curation of data, manuscript writing and coordinating contributions across co-authors. JH[1], NS & JH[2] commented during drafting and finalization of the manuscript.

IV Williams, S., **McCrory, G.,** Holmberg, J… & Lebherz, A. (2022). Opening up evaluation for sustainability transitions: Manuscript submitted to *Environment, Development and Sustainability.*

Author contributions: All authors jointly conceived of and designed the study. SW and GMC jointly organized and analyzed the data, with support from co-authors. SW and GMC jointly drafted and redrafted all sections of the manuscript, with support from co-authors.

Related outputs not included in this thesis

I **McCrory, G.,** & Schäpke, N., Larsson, J., & Holmberg, J. (2018) Governing sustainability transitions: contrasting experimental arenas through the lens of Agenda 2030. *Conference paper presented at the 9th International Sustainability Transitions Conference (IST-18).* Manchester, UK

II Rau, A. L., Bickel, M. W., Rathgens, J., Schroth, T. N., Weiser, A., Hilser, S., **McCrory, G...** & Stålhammar, S. (2018). Linking concepts of change and ecosystem services research: A systematic review. *Change and Adaptation in Socio-Ecological Systems*, *4*(1), 33-45.

III **McCrory, G.** (2022) Learning to Frame Complex Sustainability Challenges in Place: Exploring Opportunities, Tensions and Trade-offs in Educational Approaches to Transformation. Book chapter in *Van Poeck et al. (2022) Challenges for environmental & sustainability education research in times of climate crisis: 15th Invitational seminar on Environmental and Sustainability Education Research*.

IV **McCrory, G.,** & Sprowls, E., (2022) Boundaries between ESE research and practice. Podcast, Invitational Seminar ESE. Ghent, Belgium. Recorded June 2022, https://soundcloud.com/invitational-seminar-ese/episode-4-boundaries-between?in=invitational-seminar-ese/sets/challenges-for-environmental-and-sustainability-education-research-in-times-of-climate-crisis

V **McCrory, G.,** Altunay, M & Vowles, K. (2021). Transition talks webinar: When COVID cut our wings. Recorded March 2021. Available: https://www.youtube.com/watch?v=V9qJEbf6DWw

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Glossary of boundary terms central to this thesis

Boundary objects are objects that, in inter- and transdisciplinary settings, offer promise in transgressing knowledge-action dualisms. They achieve this by creating a shared object as a basis for collaboration and dialogue. Such objects are well-suited to learning arrangements whose focus lies with wider issues, challenges, or messes, as matters for the integration of knowledge and practice.

Labs: *Lab* is not a new term, and there are important differences between its use in this thesis and clinical lab approaches. In this thesis, the term '*sustainability-oriented labs in real-world contexts'* will be adopted. Although admittedly a mouthful/eyesore depending on whether spoken or read, there are reasons for this choice. Within transitions and transformations, *'Labs'* are experimental activities. '*Sustainability-oriented'* speaks to their normative ambitions. *'Real-world contexts'* highlights their authentic nature, as activities that exist in open societal systems. Each of these distinctions will become more evident as this thesis progresses. For example, they can be read in more detail in sections 2.3 and 3.

Framing: In this thesis, I draw from educational and learning sciences, systems thinking, sustainability science, political sciences and transdisciplinarity to inform framing. We maintain an open orientation with framing to allow for an emergent approach to our work. In educational settings at the level of pedagogy, framing can be understood as a: (1) conceptual or theoretical point of entry, (2) social phenomenon, mediated through language and relations, (3) continuous matter of praxis that unfolds in context.

Systems: In this thesis, systems can be understood as consisting of elements that are related to eachother. The patterns and nature of these relations constitute the structure of the system. Not only are they discrete, but systems exist *within* larger systems and *as* larger systems. Due to the hierarchical or nested nature of society, we simultaneously constitute, *and are constituted by*, systems. Within systems lie emergent properties. Systems can be *coupled*; they co-evolve in relation to one another.

Intervention: In this thesis, the term intervention spans both natural and social sciences. Intervention has historically been associated with observation as part of the experimental method. It signals a movement made by a subject on an object, a form of stepping into the natural order of things through the manipulation of a certain series of events. In educational sciences, interventions resonate with the practice of adjusting education at the level of measure, in search of effect. It ranges from the notion of intervening as an educator from the outside, to interventions as collective responses within educational settings. Evidence-driven approaches to education may for example focus on educational interventions that seek improvements in educational quality. Systems thinking focuses on *places to intervene* within a system or refers to *interventionism* as a purposeful action by an agent to create change.

List of acronyms and abbreviations

UN	United Nations
SDG	Sustainable Development Goals
C-Lab	Challenge Lab
ID	Interdisciplinarity
TD	Transdisciplinarity
UD	Undisciplinarity
SD	Sustainable development
SE	Socio/al-ecological
ST	Socio-technical
LL	Living Labs
ULL	Urban Living Labs
UTL	Urban Transition Labs
TM	Urban Transition Labs
RWL	Real-World Labs
T-Lab	Transformation labs
ESD	Education for sustainable development
ESE	Environmental sustainability education

Preface

As a reader, you may have expectations on what is to follow. After all, every PhD is compressed into a monograph or thesis by publication according to preference, and expected audience (Sword, 2012). Its form is a vital means to gauge progress towards a PhD. Under a disciplinary view, this thesis might be regarded as:

- The concluding point of a PhD that demonstrates doctoral progress
- Demonstration of discipline-specific knowledge and skills
- A base for appraisal according to learning objectives
- A standalone piece, comprising prior contributions, and claims to knowledge
- A landscape for the preparing research possibilities into the future.

What you might expect to read, then, is an account of "what I have done". By the end of this thesis, you may qualify me to say *something of value* within in a community. I hope that I succeed in pointing, with some clarity, to insights that have been closest to me in my research. Yet, as a written piece, thesis is both product and process (Colyar, 2009; Emig, 1977). Stories of *becoming* and doctorateness highlight how every single student, with their own dispositional, cultural, political, disciplinary and social form, embarks on a journey. They contain possibility and emergence, with no pre-established blueprint to be applied in advance. Aside from common competencies that doctoral studies try to foster – knowledge, pedagogical expertise, interpersonal skills, necessary habits for prolonged academic success – the doctoral journey is also one where ethical sensibility is cultivated.

It is my hope, then, that you also see how I have tried to step into my work, as "*a means of looking inward, a means of connecting with ourselves*" (Colyar, 2009, p. 429). Introspection is striking as it is a way to challenge neoliberal notions of education (Bessant et al., 2015; Freire, 2000), where knowledge is framed as a commodity (Barnacle, 2005). By adding an inner dimension to the doctoral process, I hope to show what have I done, why I have done it, how it might have been different. In other words, I hope to share what I might be *becoming* as a researcher.

Rather than narrowing, my research has been boundary-spanning. The reason for this is that, as an undisciplinary scholar, I approach real-world phenomena that recruit knowledge from across borders. This thesis does not sit neatly with dualisms such as research or practice, knowledge or action, natural or social science. This may dissatisfy some, inspire a few, and confuse others. As an uprooting concept, undisciplinarity is transgressive; it decentres discipline, disciplinary identity, disciplinary expectations of quality, and disciplinary attachments to the role of research. It begins beyond them. It is a language-in-the making, a path brought into being by walking. That does not mean that this work is a free-for-all; it has been thought through with care and attention. As you read, I invite you to reflect both upon the assumptions that ground your view of this thesis, as well as your own processes of becoming.

Part One: Thesis motivation

1 Introduction

> *No human society, however wise, subtle, prudent, and cautious you may think it to be, has had to grapple with the reactions of the earth system to the actions of eight or nine billion humans. All the wisdom accumulated over ten thousand years, even if we were to succeed in rediscovering it, has never served more than a few hundred, a few thousand, a few million human beings on a relatively stable stage.*
>
> *Latour, 2018, p. 45*

June 2022 was officially the warmest month since records began. Heatwave records were shattered in UK, Germany, Pakistan, parts of Canada and elsewhere. In September 2022, the Sylhet region of Bangladesh was devastated by generational rainfall and flooding. When this introduction was first drafted, residents in Florida were sheltering from a category five hurricane, Ian, which had made landfall. One third of Pakistan was underwater, and 8 million people had been displaced because of historic flooding. Terrestrial and marine ecosystems are witnessing unprecedented population decline due to warming and habitat fragmentation. The Horn of Africa is simultaneously experiencing both drought and famine. Southwestern North America is experiencing an 18-year megadrought, surpassing historical drought records. Had this thesis been written in 2021, 2020, 2015, 2010 or 2005, its opening might have remained more or less the same. It's warming. It's us. We're sure. It's bad. (Nicholas, 2021; Baker et al., 2019; Pörtner et al., 2022).

Yet the burdens of climate change intersect with developments such as pervasive poverty, ongoing geopolitical conflict and political reform. In the UK, highest-earner tax rates were reduced, then revoked. Then leadership was removed, in the middle a historic cost-of-living crisis. Two months of anti-regime demonstrations have taken place across Iran. In Sweden, where this thesis has been based, the government has been embroiled in political change. At the highest level of government, plans are in place to abolish the environment ministry. It is day 271 of the Russian invasion of Ukraine. As the studies within this thesis have developed, coronavirus progressed from a non-event to an isolated case, to a confusing pattern, to a contained national epidemic, to a global pandemic. For some, particularly the top 1% and even the top 10%, it has become a fading memory that marks a return to normal. All that is left is the inconvenience of wearing a mask at times, or additional security when jetting off. For many, however, COVID deepened existing inequality, poverty, loneliness and segregation.

As this introduction serves to highlight, we live in a time of compounding ecological and social change. The ongoing developments in the present imply that, one way or another, individuals, organizations, communities, cities and countries can expect fundamental change in the near future. The magnitude of such change is difficult to conceive of for many, including myself. Transitions and transformations cannot be known in advance, and with an inability to know comes systems that move simultaneously along multiple trajectories. There is a distinctly *complex* and *uncertain* nature to the tasks that lie ahead. In a world of motion, we are therefore wavering between the past and the future; between knowing and doing; between what is and what will be. We are living in a liminal era.

Contemporary forms of governance are experiencing a tension between controlling the present, under conditions of uncertainty, and urgency, and nurturing collective capacities to enact transformative change (Pereira et al., 2015; Fazey et al., 2018; Scoones et al., 2020). Because governing intersects with sustainability challenges that are complex[1], this tension can be expressed as that between solving unsustainability in the present[2], versus imagining and collectively experimenting for a better future (Loorbach et al., 2017; Pereira et al., 2015; Anderson, 2010). The impulses of the latter encourage the crafting of reflexive modes of governing, where from plural possibility in the future, action can emerge in the present. These transformative impulses are echoed by a growing community of scholars across fields – including sustainability transitions, sustainability science, action research, systems thinking, learning sciences – who are building new knowledge practices (Pereira et al., 2018; Mukute et al., 2018; Bradbury et al., 2019; O'Brien et al., Avelino & Grin, 2017; Fazey et al., 2018; Mitchell et al., 2015). Moreover:

> *Nothing less than a radical shift towards large-scale expansion of more action-oriented knowledge production will be required that: takes into account the real world of politics, values, and ethics that characterise societal change; works with academic and practical forms of knowledge; embraces creativity, imagination and innovation as a form of knowledge production; and is more explicit about its relationship to society.*

[1] There may be many reasons for this being the case, but a few are important for the framing of this thesis. First, complex sustainability challenges are not owned by single actors. Their scope is often not limited to one sector, district, or country. Second, complex challenges are multi-dimensional in nature. Their realties cannot be understood through single experiences, and their consequences ripple unevenly over space and time. Political change, environmental change and social change do not operate in isolation, but regularly feed into each other. Third, complex sustainability challenges are entangled within open systems.

[2] At the same time, meaningful action tends to remain an afterthought to knowledge-first approaches to science and society. The reactionary nature of many current political agendas seems to lead to the patching of life in the present (Bregman, 2018) devoid of a future.

Fazey et al. 2018, p.56

This thesis can be situated alongside calls to develop forms of knowledge that impact for change in the here and now. Their starting point, like mine, rests upon the following assumptions:

- Significant and *transformative societal change* is needed,
- Many contemporary challenges *cannot be addressed* by the same kinds of thinking that created them,
- Science is an inherently *normative* social process; researchers are *not independent* from that which is studied, and scientists are *interveners*. *Reflexivity* is critical
- Greater focus is needed on *learning how* to make change happen, *in* the present *for* the future.

The above assumptions provide a point of entry into this thesis. They imply a systemic assumption around change; they signify the importance of experimenting; envision new research roles to become available; and they hold explicit learning orientations. In combination, this approach to change is central in inter, trans, -undisciplinary modes of transitions and transformations research (Loorbach et al., 2017; Köhler et al., 2019; Smith et al., 2005; Biermann et al., 2017; Miller et al., 2014). Importantly, such approaches contend that transitions and transformations are not only historical developments to be analyzed and described. Rather, they are processes in the making, that require careful co-ordination across actor-sets to both understand and enhance capacities for action (Feola et al., 2015; Hölscher et al., 2021)

1.1 Research curiosity

The research contained within this thesis originated as a research curiosity. Research curiosities, puzzles or mysteries accommodate the creative role of research in interrogating existing understandings, introducing, new or presenting alternative interpretations (Alvesson, 2013). Curiosities demand a balance between societal significance, personal experiences and discourse relevant when establishing a persuasive warrant for research (Alvesson & Sandberg, 2013; Gustafsson & Hagström, 2018). Not all gaps in literature are relevant for societal issues; experience alone does not justify mystery; ill-structured societal issues can quickly curb curiosity. In addition, curiosities are distinct from gap-spotting and incremental approaches to research, which are often associated with filling a deficit,

reducing confusion or complementing what is currently known about a topic (Sandberg & Alvesson, 2011)[3].

Societal significance and discourse relevance

A recent evolution of the "experimental turn" in society, labs as catalysts of change have grown in science, policy and practice. Labs are connected to local restaurants, buildings, co-working spaces, research institutes, international projects, city districts and regions. Their allure is not only local, but also translocal and transnational (Loorbach et al., 2020). At the level of practice, the European Network of Living Labs consists of 150+ lab initiatives globally, and the UNDP hosts a learning network of 90 accelerator labs[4]. With ambitions to explore, co-create, co-produce and experiment, labs have also drawn sizable strategic investments in cities and at the European level (Voytenko et al., 2016).

In transitions and transformations in-the-making, *labs in the real world* have entered the discussion alongside a family of experimental, place-based initiatives (Bulkeley et al., 2016; von Wirth et al., 2019; Charli-Joseph et al., 2018). Topically, they draw from design traditions, urban studies, learning sciences and transitions and transformations (Sanders and Stappers, 2008; Voytenko et al., 2016; Engeström, 1987; Pereira et al., 2018). Labs coincide with shifting attention towards methodologies that are learning-oriented and participatory (Loorbach, 2007; Westley et al. 2011; Sanders and Stappers, 2008). Because of the ambition to engage with processes, they explore desirable and sustainable futures that are framed as a collective endeavour (Loorbach et al., 2017; Hilden et al., 2017). *Sustainability-oriented labs in real-world contexts*[5] therefore appear as novel and highly complex entities that situate and localize engagement with sustainability issues (Evans & Karvonen, 2014; Nevens et al., 2013; Schäpke et al., 2018).

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[3] If research is viewed as practice built upon wonderment, curiosity, mystery or puzzlement (Gustafsson & Hagström, 2018; Sandberg & Alvesson, 2011), sparks may arise through the essentially unpredictable. The work of Urban Sociologist Erik Klinenberg (2015) stands out as a poignant case where doctoral research arises out of personal attachment to, curiosity of, and confusion around an unforeseeable event – the deadly Chicago Heatwave of 1995.

[4] ENoLL: https://enoll.org/;
Accelerator labs: https://acceleratorlabs.undp.org/content/acceleratorlabs/en/home/our-work.html;
Policy labs: https://www.vinnova.se/m/smart-policyutveckling/nationella-och-internationella-policylabb/

[5] For the remainder of this thesis, the term "sustainability-oriented labs in real-world contexts" will be adopted. Although admittedly a mouthful/ eyesore depending on whether one may speak it or read it, there are reasons for this choice. 'Labs' are experimental activities within both transitions and transformations. It is not a new term, and there are important differences between its use here and more clinical lab approaches. 'Sustainability-oriented' speaks to their normative ambitions. 'Real-world contexts' highlights their authentic nature, as activities that exist in open societal systems. Each of these distinctions will become more evident as this thesis progresses. For example, they can be read in more detail in sections 2.3 and 3.

Sustainability-oriented labs in the real-world are increasingly being positioned as transformative spaces. They attract academics, practitioners and policy makers with the hope of collective, co-created outcomes. These spaces include sustainability transition labs, social innovation initiatives, and sustainability transitions experiments (Luederitz et al. 2017; McCrory et al. 2020; Bergmann et al. 2021). Broadly speaking, these labs constitute bounded settings for experimentation around sustainability challenges in collaboration with various actors (Bulkeley & Betsill, 2013; Evans et al., 2016). The language of labs seems to hold promise in working towards change that is both robust, just, and rapid. Their boundary-spanning and explicitly experimental nature enables the language of the laboratory to therefore respond to calls associated with (1) the urgent nature of pressing ecological and social challenges, (2) the inability of current dominant modes of science to resolve such challenges, and (3) ongoing social, political, economic, and educational sentiments that "things need to change".

Personal significance

Through academic, professional, and personal experiences, I have been aware of the associations triggered by the "lab" in the real world. I experienced the diverse stances that exist in lab practices yet seem to be glossed over in different fields of research and practice. Moreover, when connected to the need for explicitly normative change of a systemic nature, advocated from within the sustainability transitions and transformations community, it is striking that sustainability is broadly neglected from their understandings. This remains disconcerting, given that levels of action, from the domain of international environmental politics to the local district, are adopting the language of the laboratory and the experiment. There is a risk here that lofty ambitions obscure our understanding of the plural influences labs may offer. In addition, the taken-for-granted character of the lab may depoliticize a phenomenon that is invariably political and ethical.

From research curiosity to thesis aim

Given (1) the unfolding of the laboratory in the real world across various spheres of influence, (2) my previous and ongoing involvement in the design of labs, as well as (3) ongoing tasks to treat both content and process of sustainability, I was curious to investigate how labs are constructed as part of a broader transformative response.

From this curiosity, overarching aim of this thesis is to **investigate how sustainability-oriented labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformations**[6].

1.2 Central guiding research questions

In approaching this aim, I rely upon four complementary research questions:

1. **How might sustainability-oriented labs in real-world contexts be understood?**
2. **As an educational lab, how does Challenge Lab (C-Lab) organize around sustainability challenges, and how do such challenges unfold?**
3. **In which ways do sustainability-oriented labs engage with sustainability, and how can they be categorized?**
4. **What is the capacity of evaluation practices as a tool for sustainability-oriented labs?**

To address this aim and these questions, this thesis approaches sustainability-oriented labs in real-world contexts from three primary angles (Figure 1):

a) **In unpacking labs (Research phase one: RQ1 and RQ3),** this thesis includes a systematic, qualitative-dominant review process, with the ambition of exploring labs that have an explicit orientation towards sustainability,
b) **In designing labs (Research phase two: RQ2),** this thesis includes an embedded, longitudinal, qualitative case approach, with the intention of investigating C-Lab as a challenge-driven learning environment, and
c) **In evaluating labs (Research phase three: RQ4),** this thesis includes case-comparative research aimed at comparing the evaluative intents and experiences of labs and transition experiments.

[6] The papers that I have published, equivalent to *"my research",* comprise one of three formal activities in my doctoral journey. I have been shaped continuously in the form of teaching, and the courses that I take as a PhD student. When outlining articles, I alternate between "*I*" and "*We*" depending on whether my intention is descriptive or reflective. "*We*" recognizes the highly collaborate nature of all research phases, whereby both research and education efforts have been underpinned by collective work. In addition, at times *"We"* may also signify C-Lab as a group of designers and students, as co-learners. When discussing findings and synthesizing this thesis, I write mostly in first person, acknowledging that synthesis sits above research phases and connects to this PhD thesis.

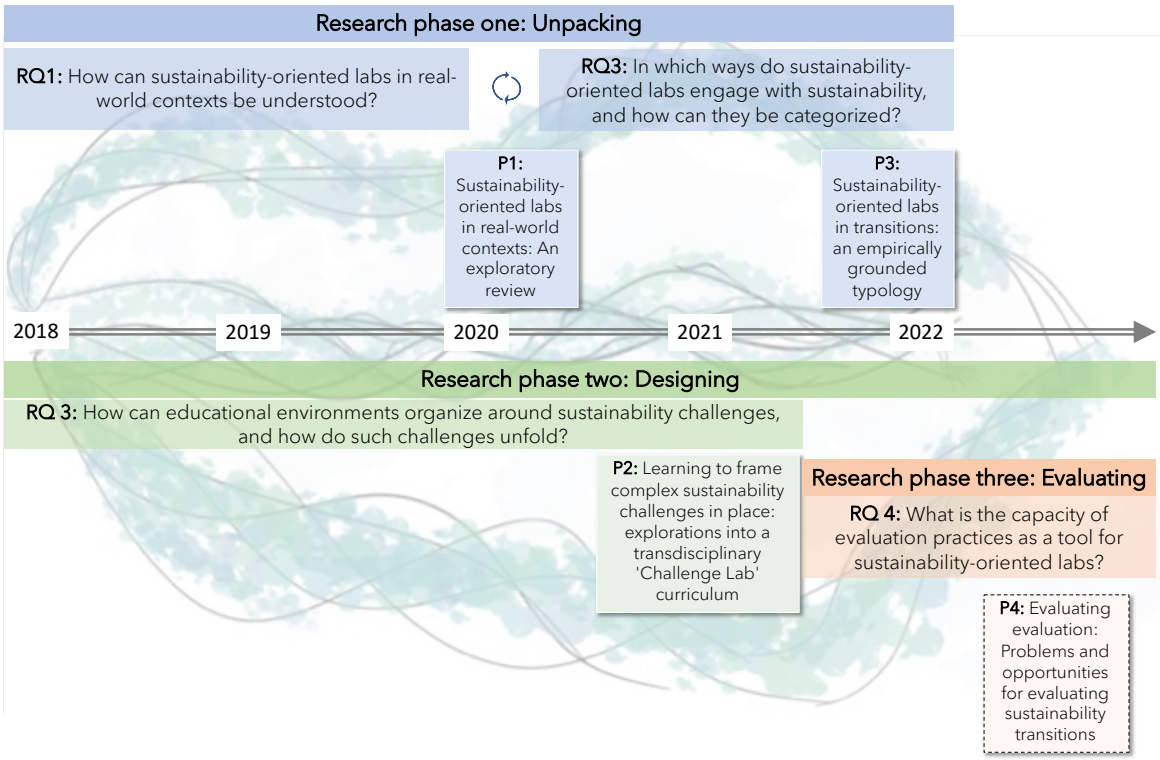

Figure 1: Overview of thesis research strategy, corresponding with research phases.

1.3 Scope of this thesis

As a phenomenon connected to a range of different disciplines, areas of practice and contexts, some decisions were made early to maintain a research scope for this doctoral study.

First, this thesis is concerned with labs that explicitly take place in real-world contexts. Labs in real-world contexts are different to classical laboratories that examine causal relations between variables in as part of a closed system (Danermark et al., 2005). Labs in the real world break these distinctions by re-situating processes of experimentation in more participatory manners. This is not a direct reversal of the logic of the laboratory, but rather a confluence of alternative interpretations focused on enriching experimentation in open social systems. Although connected to broader debates about laboratization (Guggenheim, 2012), the focus of this thesis is on lab practices that are in contrast both to "placeless" and "consequent-free" laboratories that emerged in the late 19th century, as well as an undefined use of lab as a metaphor for change. Throughout the process of locating labs in research phase one, for example, I gradually excluded metaphorical or abstract references, nation states, regions and universities as labs, and companies.

Second, this thesis held a broad scope for interpretation regarding what sustainability might mean for labs. This was an aim of research phase one, for example. It enabled the classification and comparison of various labs depending on what sustainability means, as well as how it is engaged with as a concept. As a result, *sustainability-orientations* provided an entry point for unpacking sustainability as a bridging concept across conceptual labs and roots, whose meaning is substantiated in place.

Third, in its entirety, the research strategy underpinning this thesis is one rooted in praxis, or theory-informed purposeful action (Ison, 2010). My understanding of praxis is connected to the work of both Ison (2010) and Freire (1970). According to Ison, "*Praxis is understood (more as a state of "being" or inquiry) where practices (action) and understandings (theory) are interfused through purposeful (transformative) design and application*" (p. 14). This is combined with a Freirean approach to praxis *as* action where "*human activity consists of action and reflection: it is praxis; it is transformation of the world. And as praxis, it requires theory to illuminate it*" (1970, p. 125). Therefore, in this thesis, praxis is understood as action (practices and design) and reflection informed by theory.

1.4 Structure of this thesis

From start to finish, this thesis can be read in five connected parts.

In part one, I motivate my thesis purpose (**Chapter 1**), and outline my approach as undisciplinary **(Chapter 2).**

In part two, I contextualize the background for my work **(Chapters 3, 4, and 5)** I then present the research strategy in this thesis as a combination of ontological, epistemological, axiological, and methodological considerations **(Chapter 6, see Figure 1).**

In part three, I dedicate one chapter each to the research motivations, methodological approach and findings from each research phase **(Chapters 7, 8 and 9).** I do this to provide sufficient space to trace connections between the overarching motivation and background of this thesis, and the contributions that are relevant for each research phase:

- In **Chapter 7,** I establish a normative understanding of a global sample of labs using sustainability as an organizing concept. I complement this understanding with classificatory approaches to shine light on their diversity and distinctiveness. RQ1 and 3 emerged from, and were shaped by, one continuous research strategy: a systematic yet exploratory review process.
- In **Chapter 8,** I investigate the particularities of learning that unfold within a Challenge Lab (C-Lab) curriculum. C-Lab here can be understood as an experimental

space that sits between academia, science, and society. I approach this research in an integrated manner, having been practically, emotionally, and analytically engaged with C-Lab for the duration of my doctoral journey. Connected to RQ2, I zoom in on one curriculum in 2020, weaving together expectations, events, and experiences to provide an integrated view of challenge-driven curriculum. I adopt a research strategy that methodologically pays attention to the various layers of a learning space, attempting to motivate these spaces as unfolding sites where tension and contradiction occur in the expansion of learning objects.

- In **Chapter 9**, I conceptualize and compare the role of evaluation as a tool that can enhance the transformative capacity of sustainability-oriented labs and its broader family of transition experiments. Here, RQ4 emerged from a series of sustained conversations and structured reflections with evaluation designers of three transition experiments. Its intention is to highlight the diverse and distinct ways that evaluation can be approached within such activities, and the way in which they attempt to transgress conventional challenges associated with evaluating futures that may never come into being.

In **part four,** I attempt to bring together all papers in response to the overall aim of this thesis. In **Chapter 10,** I begin by searching for cross-cutting insights from all research phases, before reflecting on the limitations of each phase. I then present a series of contributions from this thesis and the studies contained within **(Chapter 11**).

In **part five,** I critically consider this **(Chapter 12).** I reflect upon my undisciplinary doctoral process in **Chapter13**. I motivate my decision to pursue what has, in some ways, become a "one-tonne" PhD, openly exploring how staying on the ground might be both expansive and highly mobile **(Chapter 14),** before concluding with some final words for the future.

1.5 My hopes for this thesis

In its entirety, I hope this thesis resonates with inter, trans, -undisciplinary (ID, TD, UD) scholars as a possibility of packaging a doctoral thesis by publication. Rather than briefly summarizing each study, I have written above and around my work in a more dedicated manner (Chapters 7 - 9). I have also dedicated space to reflecting on my journey in a process-oriented manner (Chapters 2, 13 and 14). In addition, at various stages of this thesis, I step outside of my studies and reflect on research phases in more depth than can be found in their papers. Rather than a linear project, this thesis can hopefully highlight the framing processes that took place in arriving at each paper.

A sole focus on articles can misrepresent diverse forms of learning that occur in these modes of research (Mitchell & Willetts, 2009). It risks framing impact in a narrow manner that might not be shared by me or others. Articles are of course necessary to progress within academia, but as their value is but one line of impact, they alone are insufficient for flourishing as an undisciplinary scholar.

Within stylistic choice then, lies a space for transformation (Piotrowski, 2017; Penders & Shaw, 2020). My choice to adopt a UD approach was done to resist (1) stylistic caution, (2) self-cloning based on convention and (3) reproducing uncreative writing forms that perpetuate publish or perish[7] (Sword, 2012). Chapter 12 represents the most "current" contribution from this thesis, representing synthetic insights that are irreducible to a research phase. The first paragraph in Chapter 1 was completed last. I have found thinking through time to be a helpful resource in developing insights on processes of *becoming* [8]that move beyond linear time. Crucially, its appeal to me lies in encouraging deeper forms of learning *about* learning, as well as opportunities to resonate with various knowledge types.

At the same time, I hold my own uncertainties about whether this form is necessary, and the impacts that it might have on readership. At various stages, it has felt like a contribution, a result, a reflection, process or a structure. Its ability to shift shape and uncover new concerns might indicate that it has been helpful, regardless of the eventual form it takes.

For researchers, educators or students who are interested in education in times of transformation, I hope that chapters 5, 7, 8, 10, 12 and 13 resonate with you. Within these chapters, I point towards my attempt to balance a PhD between education and research, followed by the gradual interconnecting of the two. In the end, the educational mission became more central to my work than I could ever have imagined. Some might argue that these developments can be partly explained as methodology, in the movement from review research to case-based inquiry. I believe however that there is more that can be said about the implications of this approach on research and action. Moreover, I have felt the need to reflect on the movements I have made, to uncover more about the interplay between labs and broader educational systems, as well as how this impulse has grown from

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[7] There is a growing realization that (1) academic writing historically functioned as a mode of resistance and civil disobedience (Penders & Shaw), and (2) that it can support ongoing efforts to create safe spaces in the pursuit of caring and collaborative research in academia (Care et al. 2021; Kiriakos & Tienari, 2018).

[8] *"Becoming suggests a transformation over time: a becoming other than what one is already. Whether this temporal dimension is conceived as linear or cyclical it carries with it an implication of directedness"* (Barnacle, 2005, p. 179). Freire stresses the importance of becoming over 'Is': *"as beings in the process of becoming—as unfinished, uncompleted beings in and with a likewise unfinished reality […] The unfinished character of human beings and the transformational character of reality necessitate that education be an ongoing activity."* (2000. P.84)

within alongside others. Over time, I became a different researcher, and my views on education, whether past, present and future have shifted. Not only do I consider these changes to be invaluable for my future career, but they have also been meaningful and potentially transformative for me. Their inclusions are not intended as declarations of a practice that is 'better than others'. Rather, I remain humble in this opening, with an interest in discussing and reflecting upon interplays between researchers, research and education as matters of learning.

To actors who are purposefully engaging with lab design and/or research, I hope that chapters 3 – 12 resonate with you. Chapter 3 broadly covers research on labs in sustainability transitions and transformations. Chapter 6 contains the broader research approach this thesis. Chapters 6,11 and 12 point towards action-knowledge insights that can be drawn from this work.

To researchers actively interested in process-oriented knowledge and experience, I hope that chapters 2, 7.1, 8.1, 9.1, 11.2, 12, 13 and resonate with you. These chapters contain process descriptions of my research designs and each phase, as well as process-based experiences during this PhD. In addition, they include reflexive writing stories of various forms such as: (1) travelling conversations with early-career researchers (chapter 13, (2) descriptions of my research journey (section 2.2), (3) reflective recall around Challenge Lab (section 2.3.3), (4) a layered vision of education presented during my PhD (section 12.4), as well as (5) stories of undisciplinarity from this journey (section 13.1). These process reflections can be understood as both descriptive and autoethnographic (Ellis et al., 2011), in that they attempt to bridge personal experience with subjectivities, as well as to analyze such experiences as part of broader phenomena. Its goal is not only to show personal experience (auto), but to analyze experience (ethno) that *"helps us understand how the kinds of people we claim, or are perceived, to be influence interpretations of what we study, how we study it, and what we say about our topic"* (Ellis et al., 2011, p. 275).

In these chapters, there is subjectivity, history, thoughts, and contradiction. These might sit uneasily for some, a point that I anticipate and have considered in advance. There may have also been other ways to "show, not tell" these stories, and those conversations I openly welcome. There is also an unfinished quality to them. Recognizing the incompleteness of my work signals that one must make peace that thoughts are ongoing, cases ferment, and the threading together within this thesis is part of a longer journey of becoming. In addition, it marks a commitment that I have taken to learn more about 'what and why I do what I do, when I do what I do' (Ison, 2010).

To actors actively involved in evaluation practices, and the topic of evaluating transitions and transformations, I hope that chapters 4, 9, and 10 resonate with you. These chapters set the basis for the uncertain nature of transitions and transformation, as well as the complexities involved in navigating change. In addition, they outline the importance of experimental evaluation as a promising avenue for experimental practices.

To anybody who is actively questioning how, why and where they move as part of their lives of inquiry, I hope that chapter 14 resonates with you. I made the choice to stay on the ground during my PhD and have only started to explore this choice as part of an uncomfortable and often unspoken space in research. Chapter 14 can be understood as an autoethnographic inquiry of my experiences while travelling by train, bus and boat. These experiences are expanded via research on flight-free academia, relational experiences as well as relevant literature. The intention of this chapter is partly to witness and place my own experiences alongside prevailing notions of academia that are highly mobile and underpinned by flying. I realise that the affordances to stay on the ground are not shared, and that the actual practices of flying equally distributed. I also acknowledge that carbon inequalities of mobility mirror wealth inequalities, and that flying is but one mode of mobility. For this reason, this is not intended as a blanket critique, but an attempt to understand how these threads intersect when one begins engaging in academia beyond flying. This experience has been rewarding and challenging, full of soul-searching and hopeful optimism.

2 Undisciplinary orientations

> *Undisciplinary describes (1) the space or condition of early-career researchers with early interdisciplinary backgrounds, (2) the process of the journey, and (3) the orientation which aids scholars to address the complex nature of today's sustainability challenges.*
>
> *Haider et al., 2018, p. 191*

I have pursued an undisciplinary (UD) approach to research. Uncharacteristic of disciplinary doctoral journeys, the UD process involves spanning numerous fields and disciplines of research. As both a process and a space, UD enables the researcher to read, write and become in a fluid manner. Here *"there are no boundaries to guide you, but also no boundaries to hold you back"* (Haider et al., 2018, p. 199).

2.1 The undisciplinarity impulse

> *The greatest complexities arise exactly at boundaries. There are Czechs on the German side of the border and Germans on the Czech side of the border. Forest species extend beyond the edge of the forest into the field; field species penetrate partway into the forest. Disorderly, mixed-up borders are sources of diversity and creativity.*
>
> *Meadows, 2008, p. 95*

There are growing calls to broaden the forms of knowledge relevant for transformations and transitions, and to bring science closer into contact with lived matters of concern. The rise of interdisciplinarity (ID) and transdisciplinarity (TD) modes are attempts to do so, by way of both academically and societally-driven forms of science (Lyall, 2019). UD marks a departure from disciplinarily trained researchers that gradually veer towards ID and TD modes over time. It can be understood by Robinson (2008) as a mode of science that is problem-based, integrative, interactive, emergent, reflexive, and collaborative. Importantly, UD impulses arise from within early-career researchers who live at the borders and edges, and who may have never identified with one knowledge community.

I belong to a generation of scholars where the impulse *to undiscipline* is strong (Haider et al., 2018; Robinson, 2008). It can take shape as a general concern that knowledge systems that sustain science are complicit in unsustainabilities that are internal to these systems. UD

impulses can be expressed via transgressive responses to (1) disciplinary indulgence, (2) the elevation of scientific knowledge over other forms, (3) knowledge asymmetries from within and across disciplines, (4) restrictive views of the roles of research, (5) notions of objectivity and value-neutrality in academia, or (6) restrictive views of impact and success. Borne out of this concern is a tempered form of care for ways of being and acting in the world, as well as a search for humble forms of learning. By approaching challenges that elude the boundaries set by disciplines, the hope is that UD can enact change in and through academia (Vogel & O'Brien, 2022).

Although UD may seem like a rooted response to the symptoms associated with modern academia, it also exists as a space of immense possibility. By side-stepping disciplinary convention, UD can promote alternative lines of questioning and praxis. In essence, it begins with the conviction that radical change is necessary, and that academic institutions are central to this. Research is treated as a site for reparative and emotional work, where ethics can be made explicit in knowledge practices. As a transgressive act, it promotes what O'Brien (2021) refers to as a 'perspective on perspectives'. UD, then, can inspire creative relations between science and society, a sustained focus on care and well-being, and transformative understandings of impact in, through and from academia.

Given the tenets of UD described by Robinson (2008), UD promotes practical and process-based methodologies. This often means that UD researchers explore new terrain by bringing experimental practices into contact with, and beyond, convention. Given that they are often pursued at an early-career stage, navigating UD journeys naturally brings with it a high degree of uncertainty. Haider et al. (2018) highlights three central competencies to be developed in UD journeys: (1) methodological groundeness, (2) epistemological agility, and (3) strategic navigating of institutional structures. At the same time, an explicit goal of UD research strategies is to creatively embrace uncertainty. Researchers nurture an ability to navigate fields rather than disciplines, to focus on challenges rather than ideas, and to develop a sense for where boundaries may lie. Crucially, it requires that one is conscious and reflexive of one's own trajectory in the context of surroundings, opening lines of critique and soul-searching around everyday practice. The uncertain nature of doctoral journeys, combined with the relative newness of UD as a mode, means that each attempt is in essence a unique experience.

2.2 My undisciplinary journey

Research is a social process. Behind every paper, every interview or every sample, there are people committed to a process of purpose-driven inquiry. As our research progresses, so

too does the world around us and our relations within it. It is deliberately incomplete, where our ideas and experiences may change, sometimes prompting us to reconceive our past anew. Researcher positionality is a way of giving some form to unseen layers of our research. It attempts to unravel what we "do" alongside what we are becoming. To recognize positionality is to therefore craft reflexive practice, described by Etherington (2004) as "the capacity of the researcher to acknowledge how their own experiences and contexts inform the process and outcomes of inquiry" (p. 32). Below, I have taken a conversational approach to reflecting upon my position in the world around me, and as part of the development of my own normativity.

How has my personal history led to my interest in this topic?

Learning journeys are funny things. It would be difficult to "connect the dots" forward, to create a logic for life from then to now. What resonates most right now however is that the university was far removed from my imagination until, suddenly, it wasn't. During my childhood, the most important thing was to stay in school, to stay safe and to stay healthy. These things were not guaranteed in the working-class neighbourhood that I grew up in, a divided interface zone in North Belfast where scars of civil conflict ran through everyday life. There was little impulse to consider higher education at all, let alone a PhD in Sweden on labs.

As I made my way through secondary school, the possibility of continuing education began to appear. I don't recall too many conversations at home about options or trajectories. I also didn't have any single interest at that point, reflected in my choice of admittedly broad subjects such as English Literature, Business Studies and Geography. It wasn't until my final few years of school that I decided to apply for a few different degrees. Looking back, I did this mostly due to pressure from my parents, as well as the realization that my friends would also be applying for different degrees. Part of me felt indebted to pursue an educational journey; this path was unfamiliar to my family, and yet seemed to guarantee prospects of a better life. It felt exotic yet intimidating at the same time. At that point, my options were undergraduates in accounting or psychology, in Belfast or in Scotland.

I was eventually admitted to a BSc in accounting in Belfast, which I stayed with for two years. My experience was mostly social – belonging to a group, developing habits and rhythms to succeed in higher education, and learning to cram. In 2009, two tax accountants from one of the big four firms presented "a day in the life". I suppose it was a sort of inspiration talk, to give a sense of what is to come; for me, it was an awakening. I'm in the wrong place, this degree is one-dimensional, the world is more complex than this. I applied for BSc geography

in the same year, curious to learn more about a topic that had held my attention in school but never felt "serious" as an option. It was here that I learned about climate change and human-nature interaction; I learned about gentrification, globalization and inequality. I was introduced to the romanticization of the car and the plane, about the power imbued in maps, and the aestheticization of nature. These impressions were enriching, expansive, everlasting; they filled the world around me with new meaning.

Towards the tail end of my undergraduate, I remember exchanging with a fellow participant in an Erasmus Summer School. We were in Cyprus, and it was in August 2013. We were chatting about the future and next steps. I had naturally expected everyone who studied at QUB to stay. Personally, I had already accepted a master's in environmental law. One colleague mentioned that she was moving to Gothenburg to start her master's degree in Global Studies. Why? "Tuition is free, education is amongst the best in the world and Sweden seems like an amazing place to live". Sweden? More international education? Moving away is a possibility?

> *As soon as I got back, I started trying to decide whether to stay or go, emailed Anastasia and Satish for advice. Anastasia said to stay in Queen's (which was surprising) and Satish hasn't replied, but the more I look at the courses the more I'm impressed with the Masters in Lund, really think I'll regret it if I don't go. The Queen's one is so restricted it only covers policy and I'm interested in loads more. I'm almost certainly going to go, so the next year will basically be saving and planning for travel and study, pretty exciting like!*
>
> *Personal mail exchange, September 2013*

I reached out to a professor and friends for an exchange on options, but recall making the decision quickly, almost as if I was looking for a reason to step back from the masters in Belfast. I cancelled my application, worked two jobs for a year, applied for a personal loan. After being placed on reserve for a masters in Sustainability Science in Lund, Sweden, I eventually got in.

My masters education was international, interdisciplinary and located within sustainability science, an explicitly normative field of research where that gravitates around shared problems of societal importance (Jerneck et al., 2011; Kates, 2011). The action-oriented nature of sustainability science appealed to me quite quickly, as did the critique levelled towards modern science-society interactions. It was here that concepts of experimentation and learning, envisioning the future, transitions and socio-ecological systems entered. I recall a meeting with my master's supervisor in Lund, who had been working on a project

where living labs were being explored and designed. Without thinking too much, I jumped on opportunistically, and began building a research idea built around theories of learning.

From Lund, came a researcher position in VUB in Brussels. As a smart-cities researcher, I sat within a division of communication sciences interested in citizen-centric collaboration in urban-settings. I was surrounded by do-ers, working with applied research, developing methods on-the-fly, prototyping, testing, iterating and moving forward. The experimental tendencies were fascinating, as were the design-oriented views on change. Despite my growing interests both in experimentation and testing to learn, as well as labs as suitable arenas, my work felt cramped. Its highly pragmatic nature sat uneasily with me, as if at odds with the criticality offered by geography and sustainability science.

You might read this and feel that you have found little about interest. Rather than a straightforward process in arriving at a topic, a neat extension of previous interests and training, you could say that it took time to for the topic of this thesis to materialize. My personal history has been full of muddling around, tentatively exploring new possibility and gradually unsticking myself from where and when I found myself. I wasn't necessarily destined to study at university. I did have an inclination for learning at a young age, and was quite inquisitive as a child. I didn't want to be a plumber like my dad; my hands were too soft, and I was always more interested in looking at the stones than breaking them.

When possibilities appeared, it could have been that I studied psychology, accounting, geography, environmental law, environmental studies and sustainability science, citizen science. Those that I engaged with have informed my thinking, shaped my writing (Piotrowski, 2017) and instilled an interest in me in particular events, theories or developments. Along the way, I picked up fragments of theory, methodology and philosophy of science. I also picked up a hybrid language, as well as an inclination towards boundaries and in-betweens. I probably could have written a different story in place of the one above, or not at all. But to not write this would have been to miss the messiness and relationality associated with this research journey.

How does my gender/social class/ethnicity/culture influence my positioning in relation to the topic of this thesis?

My positioning as a white, English-speaking, Irish, male, first generation academic invariably intersects with my topic. As a first generation academic with little exposure to academic life, my views of science have been influenced. For me, I notice influences in the assumed role of science and taken-for-granted assumptions around conduct. I consider myself highly sensitive to elitism and entitlement in higher education. These feelings have become more

important to me over time and across various universities in the UK, Cyprus, Belgium and Sweden. As an Irish male, raised in a republican interface zone in the north of Belfast, my views on identity interact in complex ways. Some of these ways are not readily identifiable. They will continue to unfold as research avenues emerge, and as my position on my identity shifts. Some are unspoken, likely connected to trauma from the past. Others I am still working through, as they are linked to my own process of becoming. Over time, it is becoming clear that evolving questions regarding identity have been shaped by my lack of familiarity with higher education, as well as my own cultural and historical background. For example, I think of the insecurities have followed me since I first stepped into a university. These have included worries about how I speak. Given the stigmas attached to dialect in the UK and Ireland, when I think back, I recall my introduction into higher education as having come from a place of shame, where dialect and word-choice were markers of division in my everyday life. They also included experiences with financial insecurity and the need to work multiple jobs to study. Finally, I have been influenced by a complete lack of familiarity with higher education, including education that is not segregated by gender and religion. It may well be the case that undisciplinarity is my way of responding to ongoing questions regarding identities inside and outside of academia.

Although I bring my story to this PhD, these co-exist within and alongside the lives of others. Through the many exposures from higher education, it became possible for me to become aware of my positioning as a white, native English, male, educated in Europe, and the product of western education. I carry my own entitlements and have enjoyed a level of privilege that places me in a persistently advantageous position, and implicates me in gendered, racial and cultural systemic inequality. Although I may not have thought of higher education consciously during my childhood, the structural conditions of my life made it possible for university to quickly become a possibility. These conditions that have been afforded to me are the product of forms of exploitation and oppression that are colonial. Additionally, they place me in a situation where I embody a way of living that is more carbon-intensive than much of the global population. These realities are unavoidable, however, as they are a part of my history and future.

Over time, privileges are continuing to intersect eachother. My ambition is to continue to expose my own bias, recognize this in relation to others, and when possible, leverage it in the pursuit of more equitable relations. Language learning during this PhD has made me a better learner in interdisciplinary processes and supported me in searching for meaning together with others. It has also helped me re-correct the clear privileges attached to Anglo-centric knowledge processes. Over time, I have also been able to reconnect to my own local history, through a renewed appreciation of dialect. I notice my tension in writing and

sharing these words, but also notice how I try to balance responsibility with hope, knowing that we are all living with contradiction. They have been helpful in situating my lived history through my experiences with others.

I feel that as a researcher, I carry a burden of responsibility to act a certain way in the world. With responsibility, comes a possibility to make change for the better. More often than not, my positioning opts in favour of both expanding the realm of what research can be, as well as de-centering the privileged historical notion of the scientist. Coming from a community where trust in political action and academic knowledge are received with a high degree of scepticism, I find myself wanting to bring a humble and inclusive attitude to my work. In my research, I regard those who I have engaged with as more than students, more than designers, more than teachers, more than researchers.

My discomfort with binary thinking has been triggering when I have been required to position my research in relation to a specific community, as part of a specific university or connected to a specific division. My orientation towards action-oriented knowledge, topics of experimentation and my epistemic-ontological stance are therefore responses to hegemony in science. Over time, I have reacted to specific and unifying views of what researchers do, as well as what constitutes good research. Broadly, my feeling is that such questions routinely lead to closures of possibility. These closures often come the expense of plural and evolving possibility.

These above positions – of transgressing binaries, inclusivity and humility in research – are necessary in bringing science closer to society in the search of transformative change. Researchers are best suited to navigate multiple roles with care, given the learning-oriented nature of our work. As educators, we can shape generations to come in the here-and-now; as learners, we can tailor our own learning with a high degree of flexibility; as collaborators, we have the ability to give voice to those without, to identify and surface absence, to bring creativity closer into contact with arts and fiction. All these possibilities lie at the heart of inclusive transformative research, and they are the things that excite me moving forward.

2.3 How undisciplinarity has influenced this thesis

Undisciplining this thesis has shaped both my research strategy, as well as my view of this thesis in its developed form. In some ways, a focus on the 'unseen in between' may support in articulating these influences. The 'in-between' highlights process, and impermanence. In-betweenness also denotes a movement between various states and boundaries, where processes of stability begin to unravel (Turner, 1967).

2.3.1 Research curiousity at the in-between

My interest and analytical focus, labs, exist as entities that do not sit neatly within dualisms such as research or practice, knowledge or action, science and society. In some ways, they highlight the contradiction that lies within all three. Labs in the real-world might be best understood as research-practice hybrids, where there is flexibility in how these relations unfold. They are action-oriented in that they are often positioned as ways to not only know the world but to change it. They often sit in-between science and society, and yet remain plural in the interests that they serve. Arguably, labs blur these three distinctions; they are a form of praxis at the in-between.

Science-society dualism: In engaging with labs, my research has been integrative and, at times, agonistic. The reason for this is that, as a UD/ID scholar, I am driven by real-world phenomena that demand knowledge from between and outside of disciplines. I investigate labs from various angles, with the view that "*thinking critically about practice of today or yesterday, makes possible the improvement of tomorrow's practice*" (Freire, 2000, p. 44). Methodologically, my research strategies have drawn from various knowledge communities, in combination with tacit knowledge, practical experience and ongoing experiences.

Within this thesis, I have been engaged in boundary work in various ways. Boundary objects within research have appealed to me, as they provide a corridor to move through, to promote higher-order learning. This can be seen in the topic of labs itself, as well as the relevance of challenge framing as a boundary object in educational contexts (See chapter 8). Boundary objects are agonistic in that they promote forms of tension that are to be expected when compartmentalized knowledge interacts (Akkerman & Bakker, 2011). From a research strategy, one can anticipate such frictions during work of this kind, encouraging reflexive capacities for collectively moving forward (Freeth & Caniglia, 2020).

2.3.2 Research strategy at the in-between

Knowledge-action dualism: This thesis occupies a space where, in the words of Morin (2008), classical dichotomies change in character, from either/or to neither/nor & both/and. In this thesis my interest has been to transgress the dualism between knowledge and action. Action-oriented knowledge adopts a mode-2 or post-normal approach to science and society. Mode-2 knowledge rests upon the conviction, in various ways, that "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz, 1993, p. 20). Transformations and transitions research require more than transfer and translate

approaches to science-policy education (van Kerkhoff & Lebel, 2006), or transmission approaches to education (Wals & Jickling, 2002; Eisner, 1979). It dismisses the notion of a linear forward progression between problem - knowledge – action, recognizing the unhelpful nature of this framing for engaging in place[9].

It has been helpful for me to consider my work through the lens of praxis. An ongoing challenge for me has been to balance the tensions between criticality and pragmatism that encounter eachother through ongoing praxis[10]. Moreover, adopting a broader view of the relations between knowledge and action has opened meaningful lines of reflection. Stirling (2016) claims that more integrated knowledge forms the basis of knowing-doings to governance. Here, "*that knowing, and acting are inseparable and co-constituting is far more than an intellectual commitment. By showing how reflexivity can co-exist with commitment, a highly practical fulcrum emerges for transformative political hope*" (p. 21).

Teacher-student dualism: My research strategy has embraced the ambiguous nature of research that is combined with *education* and *action*. I have been boundary crossing between researchers, educators and students in my own work. My methodological approach has been exploring boundaries around labs as learning spaces, through the establishment of normative commitments to sustainability as well as qualitative, educational research (Chapter 8). Within C-Lab, I and others have emphasized a co-learning approach that attempts to rethink relations between students, teachers and stakeholders (Lotz-Sisitka et al., 2016). In doing so, the need to move beyond teacher-student binaries has proven important. This movement has been an iterative process over years, through sustained relations in C-Lab. Rather than fixing this relation, my capacity to sense these boundaries, transgress them and engage in reflections with other co-learners is continuously evolving over time.

By making a purposeful choice to begin beyond knowledge-action, student-teacher, science-society, new possibilities for collectively orienting around research can become

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[9] It is unhelpful because (1) scientists' work is shaped by the social and institutional structures and processes in which it is embedded, (2) situated challenges require various forms of knowledge and experience, as well as the integration of hybrid knowledge forms, (3) boundaries between science and society represent obstacles to collaboration by creating knowledge-action asymmetries, necessitating the separation of the political realm as mediating knowing and doing (4) technocratic approaches to science regularly uphold inequalities within society, rather than challenging them (Van Kerkhoff & Lebel., 2006).

[10] The spectrum between pragmatism and criticality is somewhat connected to how engineers and non-engineers tend to approach complex challenges (engineers can be viewed as pragmatists by training, where they defer ethical responsibilities of "why" to build or design), where "*efficiency is pursued in the absence of criticism, when actions are privileged over thought when practice is valued and theory disparaged when practice is divorced from theory (as if that were possible) for the sake of making things work 'better'*" (Cherryholmes, 1988). Here, pragmatism is associated less with philosophical pragmatism, but with action-first conceptions that overbalance action at the expense of critical practice. It suggests what might happen if praxis is pushed to the side of action, and particularly action with a constructive logic.

possible (Vogel & O'Brien, 2022). In addition, it opens the space for forms of learning that are hard and soft, warm and cold, unintentional, tacit and ultimately actionable[11] (Brown et al., 2010; Caniglia et al., 2021; Bateson, 2021; Alves, 2013).

These lines of thinking have enhanced my ability to make sense of my internal processes across ongoing research designs and, ultimately, each research phase. They have also supported in considering humility in research. Jasanoff (2018) notes that humility is a key ingredient in systems change that is honest about:

> *…the reach of science and about when to stop relying on science or technology because the problems we face are as much ethical and political. Science fixes our attention on the knowable, leading at times to an over-dependence on fact-finding. Even when scientists recognize the limits of their own inquiries, as they routinely do, the policy world, often encouraged by scientists, asks for more research.*
>
> *p.13.*

[11] Alves (2013) refers to unintentional knowledge and incidental knowledge in contrast to the forms of learning that are pre-determined in education: "*most of the knowledge we possess is not conscious and intentional; it is incidental, or tacit, acquired as a by-product of performing some other activity*". Bateson (2021) refers to transcontextual inquiry and warm data, referred to as knowledge about living relationships rather than numbers.

2.3.3 More than case, more than classroom: C-Lab as an undisciplinary space

Reflective recall of my first experience in C-lab

My first experience of C-Lab feels fresh. I arrived in Gothenburg in January 2018 and for many in the division, the winter break had a few days left. I met with John, and we agreed that I would be part of the lab in the spring. The academic period runs from Jan-June, and the lab on paper consisted of a thesis lab where I would support. At this stage, the level of support and my involvement was a bit fuzzy. I knew I would be involved, but it seemed there was more room to shape what that could mean. To begin, John suggested I join a values activity with students in week one.

The mornings were dark and cold in January. Finding accommodation in Gothenburg as an international PhD student was tricky. For the first year, I lived in Hisings Backa, a 30-minute bus ride from Chalmers campus. 8am starts meant that I brought my breakfast, lunch and coffee on my first day at C-Lab. The learning space was located at Johanneberg science park, a few minutes' walk from campus. It looked different – it was lightly carpeted, brightly lit and spacious. The light and airy feel of the room contrasted with the bleak view outside, and with the even bleaker setups on campus. Even though the sun was yet to rise, I could see an elderly man ski around the local snow-covered football pitch.

Everyone sat in a circle together from week one, to promote a space for dialogue. I recall feeling out of place on my first day. I was yet to feel comfortable taking space as an educator, too concerned with learning the course structure. C-Lab was still hours on a contract, and not something that I thought would become emotionally important to me. I was not a student in the course and was worried about being perceived as an outsider in the space. After the first check-in, we divided into threes and practiced deep dialogue and active listening. I kept expectations low, focusing instead on appearing as a competent teacher and listener. I participated alongside students as a co-learner; I shared values of importance and reflected on them for 10 uninterrupted minutes. Looking back, I felt strange and exposed, like what I was saying diverged rapidly from where I thought it would go. I chose the value of kindness and thought of my grandmum's kindness as a child. I reasoned around what my perception of, whether trait or practice, and why I aspire towards it. What began as rambling thickened with cultural meaning and temporality.

The next person shared the value of positivity, and my mind instantly wandered towards what I expect them to speak about. Optimistic view on life. Happy childhood. Cheerful attitude. Cultural upbringing. To them, positivity provided a way to make peace with the unexpected suicide of a loved one. I was speechless, and at the same time expected to just listen. I felt so unprepared for loss and love, that I had not earned the trust yet. This day stays with me in every exchange that I have in educational settings. It reminds me of our inability to anticipate the social lives of another, and the importance of listening as an ethical act. I was so wrapped up in what could be said, to anticipate its direction and cause, that I missed the moment a person made themselves visible. To borrow the words of Lipari (2015, p. 191):

> *When speaking of dialogue and ethics, then, it is important to remember that we are not speaking of two separate things, but two dimensions of the same thing: being human together with other humans—that is, being in relationship with others.*

From 2018-2022 I have engaged in educational research within C-Lab. On the week that this thesis is printed, I will be involved with peers in a currently unfolding C-Lab curriculum. C-Lab had been established as a collective learning space where students, teachers, designers and stakeholders gravitate around complex sustainability challenges. It is a master's level space, developed within Chalmers University of Technology and, until quite recently, sitting physically in between different organizations and institutions in West Sweden (Holmberg, 2014). At the in-between, C-Lab seeks to produce space for students to think beyond their inherited disciplines. It adopts a hopeful and agential perspective on change, attempting to wrestle with the need to both think seriously about the intractable nature of the systems to be transformed, whilst maintaining a possibility that difficult change can be created together. Agency and leadership are central sensitizing concepts for curriculum, and together they provide the threads of this challenge-driven learning environment where situations are essential learning objects.

During my doctoral journey, C-Lab provided a fertile TD space to learn about praxis. Over time, the importance of C-Lab grew beyond what I had previously anticipated. Given that doctoral students are expected to split their time into research, education, and personal development, I perceived the initial stresses of being present in C-Lab as a warning sign. In one way, the need to devote more time and energy than the 20% requirement of my PhD reflected part of the challenges that such spaces face. However, I was also fascinated by the learning responses within C-Lab:

- *I don't know what I'm learning*
- *I feel a sense of grief, a sense of what "could have been" in my education*
- *I feel like we can do what we want*
- *We don't know how to move forward*
- *I have never felt so seen and understood in education*
- *This is fuzzy, when can we hurry up?*
- *I feel at home*
- *How do we move forward?*
- *You remembered my name?*

I have had the opportunity to develop alongside ambitious students who are seeking to become agents of change for a more sustainable society. A majority of my intellectual and practical exchanges take place in this space, as part of a research group central to the development of C- lab. Here, I engage as a learner, a process designer, a facilitator, a co-learner and as a researcher, reflecting the embedded nature of real-world settings common in TD approaches (Brandt et al., 2013; Kagan, 2019).

Collectively, alongside co-developers and colleagues, we continued to develop interests in better understanding the design elements of the course. Connecting to a research ambition, we began confronting the complexity that educators might need to navigate and how that can be organized. We began exploring how we could learn from the phenomena at hand as an example of a dynamic learning environment. Personally, interests in experimental forms of evaluation that can not only capture this complexity emerged.

It became increasingly clear that to understand how educational spaces such as C-Lab unfold, research must acknowledge the situated role of designers, educators, students, and evaluators. What is interesting is that there is thus no single distinction that C-Lab occupies. From the perspective of research, C-Lab is an educational case study. From the perspective of the educator, it was never a case, and bounding as one highlighted that it is was always more than that. From the perspective of a doctoral journey, C-Lab may well be a 'highly inefficient' way to balance 'teaching time' versus conventions regarding effort. From the perspective of a student, it may be a course, only to become much more than that.

The four sentiments above point towards the dilemmas of research that is situated. Each distinction – educational case, ongoing learning environment, PhD obligation, or course – highlights the loss of meaning that may occur when reductions are made on intertwined approaches to change and learning. The loss of sight contrasts with what Engeström (1987) terms *"the wholeness or whole-quality of the object or situation"* (p. 180). In this thesis and during this PhD, C-Lab is not case or course, but *both* case *and* course. It is best understood as a setting that has enabled praxis alongside others, where education, research and action are intertwined.

2.3.4 My learning journey

Read like a butterfly, write like a bee.

Philip Pullman, 2002

As motivated earlier in this chapter, UD is both an orientation and a journey (Haider et al., 2018). Giving shape to this learning process may therefore be of use to readers of this thesis, as well as other scholars. Staying with the quote of Pullman above is helpful in learning more about movements made during my PhD (Figure 2). Reading like a butterfly emphasizes doctoral journeys as a process of becoming. It resonates with the need to navigate landscapes of existing knowledge, making purposeful choices along the way.

On the left-hand side of Figure 2 are the larger knowledge communities that I have stayed with during my PhD. For me, these provided a landing point for establishing links between

my own experiences, my praxis and my ongoing research. Along the way, I sought inspiration in and between disciplines such as sociology, innovation studies, geography and learning sciences. I have also located myself in research fields that are formative stages, including transitions and transformation studies and sustainability science. There is a delicate nature to my navigation, knowing that disciplinary knowledge has its limits; practice recruits' ways of knowing that may contradict theory; tacit knowledge is often difficult to verbalize or write in words, and that; novel knowledge combinations may be required for.

The notion of epistemic agility from UD depicts the capacity to source landing points for novel combinations of theory and practice. For me, this has been important in two ways. First, it has reminded me of the need to land in ID fields or concrete situations[12] to avoid 'conceptual la la land'[13] (Haider et al. 2018). Second, it has provided an affective scaffold for movement across fields and disciplines, rendering them necessary for UD praxis. On the right-hand side are sub-fields, methodologies or concrete topics that sustained the process-side of my PhD journey. These supported in the design of educational curricula, multi-stakeholder processes that I have facilitated both inside and outside of this PhD, as well as heuristics for nurturing a UD identity into the future. A critical realist underlaboring encourages the movement towards reflexive practice, where in the words of Sayer (1992), knowledge becomes useful when it is "*practically-adequate to the world*" (p. 70).

Rather than a linear process of extracting and combining knowledge, the representation in Figure 3 highlights that although theory and practice have proceeded separately at various stages, each research phase has allowed them to dovetail and feed into one another. Continuous engagement in C-Lab as a learning space made it possible to nurture praxis at various stages, that is theory-informed practical action. For example, research phase one was heavily focused on empirically categorizing a sample of labs. Research phase two afforded more time and attention towards a praxis inquiry into C-Lab. At the same time, it coincided with ongoing engagement in C-Lab as a learning environment that encouraged experimentation between theory and practice in the development of process. Alongside research phase three, as research interests in evaluation grew, C-Lab provided opportunities to experiment at the level of evaluation to co-produce knowledge on progress.

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[12] Alongside the integrative and boundary spanning role comes the need to recognize antagonism and incommensurability, where "*the process of moving beyond the confines of a discipline and engaging with others is personally and fundamentally challenging – it 'will often require some soul searching'. It requires developing an awareness of your own epistemology and engaging respectfully with diverging views and is critical because it will change your judgements about other work*" (Mitchell and Willetts, 2009, p. 14).

[13] Haider et al. (2018, p. 196) refer to conceptual la la land as a state where jargon and concepts can hijack early-career scholars' attention if they have not been able to build competency in epistemological agility and methodological groundedness.

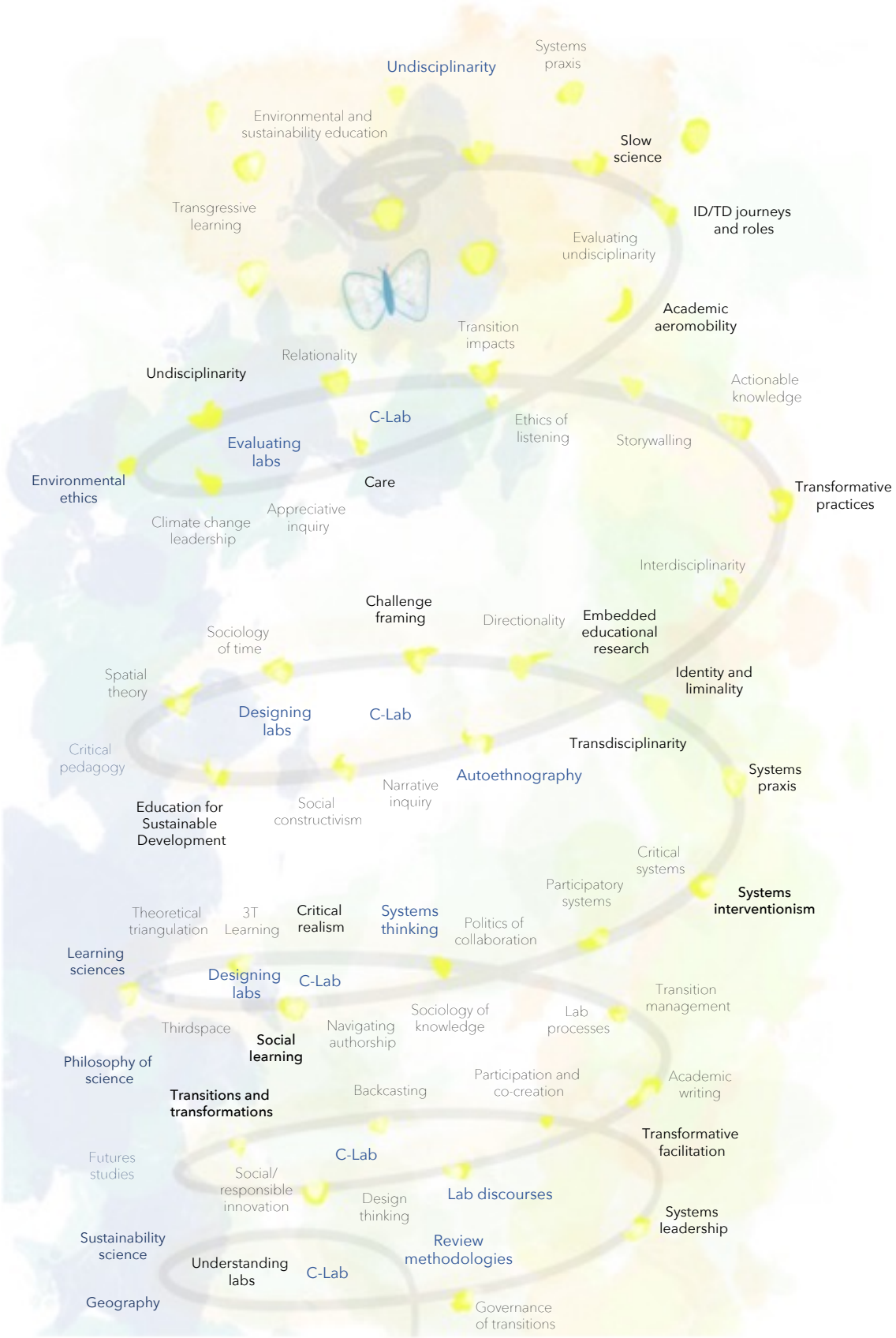

Figure 2: Visualizing my undisciplinary learning process

Part Two: Background and research strategy

In these chapters, I provide landing points that have proven fruitful for me, as well as sensitizers that broadly situate my research for the remainder of the thesis. I made this decision as the choices of orienting oneself, finding internal "*voice*" and identifying epistemic communities are not naturally pre-given. As such, the ideas and orientations run not only through each paper, but also above and around them as they inform my own development.

By the end of this part, my hope is to express three important points. **First**, that *the laboratory provides a timely research object in sustainability transitions and transformations studies (Chapter 3).* This view of the laboratory, both as a practical arena, as well as a series of concepts, provides a basis for the development of praxis (Ison, 2010). **Second**, that I approach *sustainability transitions and transformations from a challenge-oriented perspective with an interest in governing and navigating change (Chapter 4)*. **Third**, that *I lean on the concept of learning as a fundamental mechanism of change*, motivating the importance to collectively transform and transgress established ways of thinking and acting around sustainability *(Chapter 5).*

3 The Laboratory

For the world to become knowable, it must become a laboratory.

Latour, 1999, p. 43

3.1 Origins and evolutions of the lab

To some, the laboratory may seem like an odd object of study. After all, they are often portrayed as mundane, sterile, homogeneous scientific spaces. Their forms are taken for granted, and there may be strong associations with a certain form of science. Yet, in this section I hope to highlight a few things. First, that over time the laboratory has developed into one of the most heralded sites in the production of knowledge. This development has occurred alongside a particular form of science that prioritizes instrumental knowledge and mechanistic understandings of change. This secures the laboratory as an imaginary yet real kind of space. Second, laboratories in the *real-world* are benefiting from a new language and set of practices, in response to calls for more robust science-society interactions.

As a result of their development across various scientific periods, the laboratory has been wildly diverse in form (Livingstone, 2007). Historically, wherever possible, hobbyists strived to provide protected conditions in search of wisdom and truth (Livingstone, 2007; Strasser et al., 2018). From the basements and lofts of the philosopher, the laboratory existed within the homes of affluent thinkers and scientific enthusiasts. It was an attempt to carve out a sacred location where phenomena could be made visible, measurable and knowable[14] (Knorr-Cetina, 1992; Kohler, 2002; Latour, 1983). Within its confines was the attraction that one could generate something, somewhere, under a set of specific conditions that could provide generalizable insights elsewhere (Livingstone, 2003).

The historical appeals of the laboratory as a particular way of doing science cannot be understated. During the late 20th century, the prestige of those who practiced science began to carry epistemological clout. No longer the gentleman or the enthusiast, the rational scientist emerged as an elevated figure at the centre of laboratory life (Opitz et al., 2016). This development, partly due to the broader professionalization of science at the turn of the 20th century, resulted in the expansion of laboratory life as one of privilege. Boundaries of the scientist were built upon the marginalization of the non-scientist, the volunteer, the

[14] An important component of the laboratory has been to establish a closed system where one can control all factors and isolate out a single variable and reach theory/explanation on a level of universal law (logical empiricism) (Danermark et al., 2005).

hobbyist; those who had historically been central to its daily practice (Eastman, 1897). Those who, by choice or by force, were removed (and largely remain so) from the production of legitimate knowledge (Strasser et al., 2018; Vetter, 2011).

From these changes, the laboratory can be viewed as a space of separation, and one of numerous examples of the exclusionary nature in the making of modern science (Opitz et al., 2016). Processes of excluding the non-scientist had been initially uneven, but they were instrumental in resigning the public to the familiar binaries within the science community today (van Kerkhoff & Lebel, 2006; Vetter, 2011). Strasser et al. (2018) discusses the exclusionary effect of science as a profession, and positivism as a unifying approach:

> *…laboratory space has conveyed a range of meanings. There have been occasions when it assumed the role of theater as knowledge moved from its point of origin to public disclosure it frequently had to be dramatized to be stabilized. The space of experiment was also theatrical in that this is where various stagings of nature took place; in the microworld of the lab, aspects of the world were manipulated, controlled, and reconstructed courtesy of the available technology and the local experimenter's know-how. Indeed, it was only by operating material apparatus in the laboratory that such invisible entities as lines of magnetic force could be made manifest. At the same time the laboratory's very construction was routinely seen as a decisive cognitive move in the campaign to establish new ways of knowing.*
>
> *Livingstone, 2003, p. 27*

Many years since their first physical form, the notion of the laboratory as a site of truth remains. Progressing hand-in-hand with reductionism and empiricism, the laboratory is regarded as a central site of praxis (Kohler, 2002). Its equipment, objects and infrastructures constitute the material conditions for mechanistic forms of knowledge. Socially, the patterns of interaction inside and outside of laboratories have naturalized "*lab life*" (Knorr-Cetina, 1992; Latour, 1983). Politically, the notion of labs as "*truth spots*" has been upheld through the epistemic authority that it carries (Gieryn, 2006; Kohler, 2002). This elevated form of knowledge, predicated upon the closure of systems and reduction of complex multi-causality, is visible in the status of laboratory experiments and randomized control trials, widely considered to provide the most convincing evidence base for decision-making[15] (Sovacool et al., 2018; Sayer, 2002).

[15] From a critical-realist perspective, laboratory science motivated for Bhaskar (1975) a transcendental critique of positivism. His argument is that the laboratory functions as an enclosure that enables empirical regularities

The field of Science and Technology Studies (STS) made various attempts to open up the black box of the laboratory (Knorr-Cetina, 1981; Latour & Woolgar, 2013; Lynch, 1985). Of growing interest to STS was the complex interplay involved in the production of knowledge, not as a solely cognitive process but rather an embodied cultural practice (Latour, 1983). Aside from the more procedural aspects contained within the experiment, interest grew in the laboratory as the enabling context within which experimentation occurs (Knorr-Cetina, 1992). From the studies into the shaping and construction of this knowledge in laboratories, authors claim that:

- Lab practices have been mystified by a narrow focus on the procedural aspects of the experiment (Kohler, 2002; Latour, 1983)
- The notion of the laboratory is underpinned by the social and material construction of boundaries, creating an inside/outside dichotomy (Knorr-Cetina, 1992; Latour, 1983)
- Laboratories are not immune from social forces, but rather impregnated and shaped by them
- Laboratories are political spaces, where new sources of politics are generated through control and objectification
- Labs are epistemological and ontological interventions – they deeply shape the social and natural (Guggenheim, 2012; Latour, 1983)

3.2 The real-world turn: Labs in real-world contexts

More recently, in discussions around experimenting for social change, transitions, *labs in the real world* have taken a new meaning. Labs can now be found not only as sites of scientific observation; they resemble more open-ended place-based activities where processes of experimentation[16] occur within society. Because of how they braid together research and

to be *produced* inside. It assumes a closed system, that can be explained via a constant conjunction of events. (Vass, 2022)

[16] Increasingly, labs and experiments occupy similar terrain in terms of their assumptions around change. Although there is significant overlap in their characteristics, some lines of distinction are regularly drawn. Historically, experiments often highlight the processual nature of the experimental method as routinely existing within the laboratory. For some, the laboratory provides a material boundary for experimentation, signifying a specific "place" of learning when transferred to real-world contexts. Within transitions and transformations, this distinction is treated with ambivalence. For example, socio-technical systems research maintains a connection to the notion of the experiment based on its historical roots with socio-technical experiments and experimentation (Sengers et al., 2016). The infusion of geographical writing on the laboratory (Karvonen & Van Heur, 2014) has contributed to both sides of the debate, describing experimentation as a practice, and laboratories as sites of experimentation. They refer to experimentation as "*(1) involving a specific set-up of instruments and people that (2) aims for the controlled inducement of changes and (3) the*

action in a context (Bradbury et al., 2019; McClintock et al., 2003), these labs embody a need to engage *with, in and for* the real-world. The modern laboratory "buzz" includes at least four emerging usages of the laboratory: (1) labs as an undefined form of collaboration, (2) framing 'society as a laboratory', (3) labs as a local place of research and (4) labs as an institutional container to test (Guggenheim, 2012).

Laboratories in real-world contexts differ substantially from clinical or R&D settings. On the one hand, contrasts are so clear (Evans & Karvonen, 2014; Guggenheim, 2012) that it begs the question, why are we using the term? After all, they are not placeless (Kohler, 2002), but explicitly tied **to place** (Frantzeskaki et al., 2018); they do not distance from an object of inquiry (Knorr-Cetina, 1992), but **embed** within a context (Gibbons, 2000); they are not driven by controlling the natural (Latour, 1983), but acknowledge the **instability and open-endedness of the social** (Sayer, 1992). On the other hand, the value in the term lab may lay in its contradictory nature. By inflecting conventional associations, labs in real-world contexts empathize a more inclusive physical and discursive space where knowledge practices might occur. These claims can be derived in more plural ways; through sociological inquiry in the city (Gieryn, 2006); through local, place-based research (Guggenheim, 2012; Smith, 2017); by positioning the university as a sandbox (Beecroft, 2018) or via participatory processes and co-creation (Menny et al., 2018).

In the context of sustainability, implications of labs for sustainability transformations are suggested on various levels of impacts or outcomes[17]. As TD approaches which engage with systems in society, labs may establish around issues of concern that are either pre-defined beforehand or collaboratively identified through process. This arrives from the view that there is an experimental nature to sustainability (Robinson, 2004). Labs themselves carry promise as an array of safe or low-risk interventions that promote learning-by-doing and carry transformative potential (Nevens et al., 2013). In addition, labs exist as research infrastructures that enable embedded forms of observation of thematic domains in a particular place (Schäpke et al., 2018; Andersson & Rahe, 2017). They can be understood as hosting and catalyzing processes in order produce outcomes that can contribute to

measurement of these changes. These aspects of experimentation are not essential characteristics; they are mutually" (p. 383).

[17] From a sustainability and transformations perspective, labs are routinely referred to as "niches", presenting opportunities to explore unchartered territory by providing space to test and learn in real-world contexts (Bulkeley et al., 2016). They are seen as experiential interventions, carrying forward conceptual and practical interest in transformative forms of learning. The concept of niche finds itself as a central concept within dominant socio-technical frameworks such as the multi-level perspective (MLP), as well as strategic niche management. However, given its heavily technical and organizational connotation, as well as the risk of reducing non-linear interplay within the MLP, we made the choice to hold a more unconstrained conception of labs.

transformation (Luederitz et al., 2017). Rather than readily established interventions, labs can also emerge from ongoing learning processes in contexts, signalling a need to organizationally experiment with new ways of doing things (Puerari et al., 2018).

The diversity above relates to a central distinction between perspectives in transition and transformation processes. Namely between descriptive-analytical thinking *about* change dynamics often taking place at larger scales, and the prescriptive application of place-based governance *to approach* sustainability challenges (Feola, 2015). Labs are situated at the intersection of both, focusing on the place-based governance of sustainability challenges, but generating insights on dynamics on local and larger scales via processes of transfer, scaling and amplification (Lam et al., 2020).

3.3 Transformative impulses and critical junctures in lab praxis

Whilst not a comprehensive overview of what has been done, this section complements the broader overviews of lab discourses found in Chapter 7 and papers I & II. Recent contributions from Pereira et al. (2018, 2020), drawing from the fields of sustainability science and socio-ecological systems thinking, compared transformative spaces in the global south. This study distinguished five discrete phases for understanding how such spaces can be meaningfully orchestrated and brought into being when in pursuit of transformative change. From this comparison, they point towards reflections for future praxis:

- There are *ethical dilemmas associated with creating a transformative space* in a system.
- It is important to *assess the readiness of the system* for change before engaging in it.
- There is a need to balance between *'safe' and 'safe enough'* spaces for transformation.
- Convening a transformative space requires *an assemblage of diverse methodological frameworks and tools*.
- Transformative spaces can act as a *starting point for* institutionalising transformative change.

As part of ongoing efforts to create spaces for experimentation within systems, the recent work by Williams & Robinson (2020) studies evaluative challenges associated with labs and complementary experimental initiatives. It develops new frames for experimental practice that engage with plural actor and knowledge bases. In addition, this work speaks to

transitions researchers and practitioners who are actively attempting to link place-based experimentation with broader geographical and temporal processes of change (Luederitz et al., 2017; Lam et al., 2021). Their work introduces the notion of system effects in transition initiatives, bringing with it a distinctly anticipatory approach to tracing the dispersed impulses that labs and experiments may create.

Given the proliferation of labs and complementary initiatives as part of an experimental turn, it is important to turn to topics that warrant critical attention.

First, there is a tendency to positively frame experiments and labs, as if their local character is synonymous with good intentions (Collins, 2020) or transformative change (Caprotti & Cowley, 2017)**.** In part, it is symptomatic of the broader view that experimentation is positive. However, historical processes of experimentation and intervention bring with them ethical baggage. Caprotti and Cowley (2017) reminds us that the language of experimentation carries overt and sometimes dreadful associations of control and manipulation, and that such associations implicitly perpetuate unethical practice. After all, *"not all experiments are aimed at socio-environmental progress, nor are they all progressive*" (Caprotti and Cowley, 2017, p. 1447).

In real-world contexts, the above tendency appears in labs that are themselves normative and counter hegemonic. If terms such as labs and experiments are treated with ambivalence, then their grounds for intervening in social change may become tangential or counter-productive to sustainability. For example, is not uncommon that labs pre-suppose innovations of a certain form, which might limit transformative change in relatively tight space-and-time frames (McCrory et al., 2022). This can actively occur when sustainability is relegated to the environmental performance or the financial longevity of lab activities (Hossain et al., 2019). On the one hand, the blurred lines are to be expected of a phenomenon whose roots are found scientific, practical and commercial domains. On the other hand, there are lingering questions about the extent to which labs processes espouse co-optation, tokenism or even overt greenwashing.

Second, scholarship on labs and experiments may bring with it deeply rooted assumptions that scientific institutions lay claim to the motivations for, and impacts of, experimentation. This assumption, with links to empirical realism and the professionalization of the scientist in society, is marked with tensions regarding how researchers can normatively engage with transformations best. For example, although labs in the real-world actively challenge the notion of researchers as observers, one could question where the role of scientist in defining matters of concern remains upheld. Its premise is that the performances of experimentations may be more open, but science is the orchestrator (Alsonso-Yanez et al. 2020). In parallel, lab approaches span the societally driven

to research-driven (Schäpke et al., 2018), as well as from the solutions-oriented (Lee et al., 2011) or challenge-oriented (Charli-Joseph et al., 2022). Towards the research-driven and solutions-oriented side of this spectrum, Asenbaum & Hanusch (2021) note that:

> *Other accounts of labs, however, take a more instrumental approach and frame participants not as democratic subjects but rather as research subjects. Participants are seen as a source of knowledge and as users whose experiences can be exploited. Here, participants are controlled by the lab conductors who place their subjects into pre-defined settings in which their reactions to certain stimuli are monitored. Labs are employed as tools to generate marketable products when a "crowd [is] used to generate innovation"*
>
> *p. 4*

Moreover, these contradictions are but one thread in a thicker narrative about the asymmetrical nature of academic knowledge in change processes (Fritz et al., 2019: Ottinger, 2010; Bäckstrand; 2003; van Kerkhoff & Lebel, 2006). At its worst, then, by reinforcing a mechanistic and linear approach to interventions, labs and transition experiments can be misconstrued as strategic tools for controlling change within closed systems. Within this narrative, Asenbaum & Hanusch (2021) note that labs are essentially "*torn between the democratic values of agency, inclusion, and transparency and the technocratic values of control, exclusion, and opacity*" (p. 5).

As a result of the two concerns above, there is a heightened call for *reflexive lab practices, participatory process development, and attention to power and coercion in social processes* (Meadowcroft, 2009; Avelino, 2009; Stirling, 2008). Because transitions and transformations require nuanced accounts of the role of failure as internal to experimentation (Collins, 2020; Meadowcroft, 2009), there is a need to situate and contextualize success, to critique speculated impact, and to cast attention towards failure and inertia within obdurate systems. They also suggest that the assumptions around control may be deeply rooted and requiring continuous engagement beyond the pragmatics of method. Researchers that embrace ID, TD, UD stances routinely include creative and plural research roles, such as those advocated by McClintock et al. (2003): (1) research-as-action; (2) research-as-narrative; (3) research-as-facilitation; and (4) research-as-responsible. This variety may be seen as helpful in approaching the discomfort that directional, multi-stakeholder processes often necessitate (Temper et al., 2019; Wittmayer & Schäpke et al., 2014).

4 Transitions and transformations towards sustainability

Life can only be understood backwards, but it must be lived forwards.

Soren Kierkegaard

4.1 Sustainability

> *The unresolved dispute between the limits discourse and Prometheans could be put behind us, and environmental problem solving could proceed with renewed vigor in the knowledge that solutions are available that can respond effectively to a range of key ecological and economic concerns. Throw in commitments to global justice through the eradication of poverty and to the wellbeing of future generations, and the prospect would surely be irresistible. But what could possibly combine ecological protection, economic growth, social justice, and intergenerational equity, not just locally and immediately, but globally and in perpetuity? The answer is sustainable development, which specifies that we can have them all.*
>
> *Dryzek, 2013, p. 145*

In this thesis, I approach sustainability transitions and transformations from a *challenge-oriented perspective, with an interest in governing and navigating change*. As highlighted by Dryzek (2014), debates around sustainability have the incredible ability to evoke both incremental and radical conceptions of change. As a threshold concept, sustainability manages to hold polar bears, coral reefs and electric cars as somehow connected to each other. In recent years, however, stories of sustainability have focused primarily on the unsustainability of the present. The Anthropocene has been introduced to herald a new geological epoch where human impact is irreversibly changing the structure and function of planetary systems (Steffen et al. 2015). It is an era marked by acceleration, both in the interconnection between humans and nature, as well as the asymmetric relation between the two (Abson et al., 2017). The more connected we realize we are, the more we realize that the current nature of the connections require reconfiguring. The extent of this asymmetry is often presented through baseline scenarios, planetary boundaries, co2 emissions and degrees of warming (Pörtner et al., 2022; Rockstrom et al., 2009). Human

activity is placing irreversible strain on life-support systems in the planetary, which are in term shifting the conditions for humans in the present and future (Olsson et al., 2014; Priebe et al., 2020). This reinforcing loop looks bleak. If the story of sustainability was a book, we know the introduction, the middle is unfolding unevenly before our eyes, and there is a cliff-hanger with conclusions that do not look good.

However, the above story is but one way to think about sustainability. This thesis concerns itself with a different chapter in the making. Alongside the consensus that there is urgency, climate change is framed as a symptom of deeper forms of unsustainability. Transitions and transformations[18], then, entail fundamental changes in the very systems that *produce* unsustainabilities such as climate change. Approaching sustainability is viewed thus as not only a matter of diagnosis and prognosis. Rather than "fixing" or "controlling" the climate, transformations *towards* sustainability open spaces to build alternative futures in the present. They also pay attention to multiple realms that need transforming, such as justice dimensions, unequal power relations, human-nature disconnection, and various forms of oppression (Loorbach et al., 2017; Lotz-Sisitka et al., 2015; Gram-Hansen et al., 2021; Scoones et al., 2020). In short, this story opens for a movement from adaptive to transformative capacities that can: "*imagine, enact, and sustain a transformed world and a way of life that is in balance with the carrying capacity of our earth, and where all life flourishes"* (Ziervogel et al., 2016, p.2).

So, what can sustainability mean in all of this? Well, across the last several decades in international environmental discourse, sustainability has garnered a multitude of meanings and definitions (see Hopwood et al., 2005 for an overview). Here it is a concept capable of mobilizing, particularly when practiced concretely in context (Jacobs, 1999), whose importance is underscored in policy (United Nations, 2015) and research (Bai et al., 2016; Köhler et al., 2019). Moments of definition are usually marked by international gatherings or treaties. Such events signal attempts to mobilize around, reflect upon and assess the state of global affairs in the context of pressing matters of concern. They create a discursive basis for conveying what is wrong, and what we can do about it. Undoubtably the most well-known and enduring definition for Sustainable Development is that from the Brundtland Commissions Our Common Future report (WCED, 1987, p. 35), which states: "*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". More recently, embedded within Agenda 2030 (UN, 2015) is a view of sustainability as necessary in guiding multiple and major change processes in the coming decades. Agenda 2030 brings with it a heightened

[18] Feola (2015) defines transformation as *"a major, fundamental change, as opposed to minor, marginal, or incremental change, appears to be widely agreed upon in both research and policy"* (p. 377)

awareness of the *need to transform*, that transformations are reliant on *deeply integrative* efforts, and that transformations must carry a *strong ethical and moral imperative* in the context of ongoing challenges.

Historically, the substance of sustainability has changed alongside evolving understandings of the relationship between social-technical-ecological systems. These three elements are commonly associated with the social, environmental and economic dimensions of sustainability (WCED, 1987). In relation to "what" of sustainability, historical debates have differed between strong and weak sustainability depending on how one is 'allowed' to substitute between capital[19] (Daly, 1990; Solow, 1993). Over time, factors have been included gradually extend beyond the environmental realm. These included a nuanced interplay of human/nature systems, heightened recognition of the social realms of sustainability, as well as appreciation and expansion of human-needs and well-being (Holmberg et al., 1996; Holmberg & Larsson, 2018; Max-Neef et al., 1989). Similarly, it has seen the involvement of broader perspectives, moving from environmental protection to encompass equity, justice and well-being (Sneddon et al., 2006). These movements have not been without tension. As the term became more inclusive with regards to identifiers, many have argued that sustainability has suffered from a lack of meaning, been subject to greenwashing and been conflated alongside transformation to mean any kind of change at all (Zizek, 1989; Jacobs, 1999; Blythe et al. 2018).

As discourses around sustainability have evolved, various approaches to engage with sustainability have grown over time. A scale exists between sustainability as a precise, unified and objective unit and as social in character, pluralized and at the level of principle (Waas et al., 2011). In the case of the former, discourses around sustainability are expressed as a technocratically-oriented and economically motivated form of action. As sustainability agendas rise cities, regions and countries, the dominant response – techno-fixes and financial instruments – persists. This response is routinely legitimized by the language of planetary governance (Blühdorn & Welsh, 2007; de Vries, 2019). The relevance of economic choice, as well as top-down mechanisms for change, stems in part from previous narratives concerned with the depletion and substitutability of capital (Daly, 1990; Solow, 1993). More recently, they have been expressed in grand scientific frameworks such as planetary boundaries concept (Rockström et al., 2009).

Linked to the latter end of the scale is an egalitarian and contextual understanding of the environmental, social and economic challenges faced by society in particular places and at

[19] As argued by Boda and Faran (2018), the stance taken by Daly (1990) suggests a more far-reaching normative shift towards decisions not only informed by economic choice but regulated by political choice.

particular times (Sneddon et al., 2006; Stirling, 2009). Regarding scales of sustainability, environmental discourse has witnesses a growth in local "*implementation*" and multi-level governance approaches (Hooghe & Marks, 2003; Jacobs, 1999; United Nations, 2015). Rather than relying on universal indicators and expert guidance, here sustainability is a socially constructed matter of concern, graspable only through the perspectives of actors in their context (Ison, 2010). Rather than both extremes, a situated approach to sustainability represents what Sneddon et al. (2006) labels a pragmatic middle path**;** a multi-faceted and dynamic approach that attempts to connect multiple realms of knowledge in an explicitly normative, purposeful, and learning-oriented manner. Here, sustainability is regarded as:

> *The emergent property of a conversation about desired futures that is informed by some understanding of the ecological, social and economic consequences of different choices.*
>
> *Robinson, 2004, p. 381*

4.2 Transitions and transformations

This thesis is situated within the broad field of sustainability transitions and transformations. Sustainability transitions and transformations provide an organizing frame for conceptualizing change at the level of systems. Fundamental changes in systems occur on a level of consumption and production, termed "system innovations" It is argued that change of this magnitude presupposes fundamental transformation of a qualitative nature. Such fundamental change arises from within overlapping systems and sub-systems in society, including production and consumption (Hargreaves et al., 2013; McLellan et al., 2016); urban and rural (Bulkeley & Betsill, 2013; Lawhon & Murphy, 2012); natural and social; Olsson & Jerneck, 2018); structural and agential (Fischer & Newig, 2016; McLellan et al., 2016; Seyfang, et al, 2010).

In this thesis, an inclusive view of transitions and transformations is adopted. As introduced in Chapter 1, this work expresses a need for fundamental change. From a transitions and transformations perspective, then, fundamental change can be located at the level of systems. Transitions and transformations therefore advocate for not change of any kind, but *systems change, systems innovation* and *systems transformations* (Elzen et al., 2004; Geels, 2002; Grin et al., 2010; Irwin, 2015). Several studies have attempted to differentiate both fields (Hölscher et al., 2018; Rau et al., 2018) whereas numerous sub-perspectives exist also (Loorbach et al., 2017; Feola, 2015). Where these communities differ results largely from their own historical developmental, as well as etymological backgrounds from which they have sprung. Depending on the ontological-epistemic point of departure, and specific training,

each conceptualization may sit within one another at the level of discourse (Geels, 2010; Hölscher et al., 2018)[20]. Although an important debate, this thesis will not dedicate significant time or attention to unpack fields of transitions or transformations.

What I feel is important to make clear is that my *thinking and writing is informed via an engagement from both transitions and transformations communities*. There are three main factors that sit behind this choice:

1. **Working between fields promotes epistemic and methodological pluralism (Haider et al., 2018).** This is particularly true for transitions and transformations communities, given that both share historical interests in transgressing and moving beyond disciplinary knowledge boundaries (Feola, 2015). In paper II, for example, our focus on a C-Lab course is located in connection to experimental forms of education in university. Not only do these labs have plural connections to both transitions and transformations communities, but C-Lab also itself draws from both communities at the level of pedagogy, tools and process development and orientations towards change. This versatility is common within process-oriented approaches that emphasize collective learning processes whereby tools serve as learning artifacts (Feola, 2015; Hebinck et al., 2022; Loorbach et al., 2017; Pereira et al., 2015). Its advantages are summarized by Feola (2015):

> *The solution-oriented perspective can, in principle, accommodate a looser, non-substantive definition of concepts than can be encompassed by descriptive-analytical approaches. This approach values creativity and problem-solving, and prioritizes the wide applicability of concepts—which favours the wide involvement of actors in the participatory (e.g., social learning) process, and in general accepts that some concepts have 'families of meanings' rather than one single meaning. A vague definition of transformation allows for recognition of the different meanings that the concept might have for different social actors. In addition, prescriptive and value-laden interpretations might be accepted and actually favoured as a basis for negotiations and the construction of a common ground for participation […]*
>
> *p. 386*

[20] For a more detailed account on relations between transitions and transformations, see Hölscher et al. (2018), Rau et al. (2018) and Feola (2015).

2. **As highlighted in chapter 7, sustainability-oriented labs in real-world contexts are present in both communities.** In papers I and III in this thesis, socio-technical transitions provide a broad framing for labs, given their varied roots. In paper IV labs and transitions experiments have originated in both transitions and transformations communities, often as a by-product of a disciplinary background, special call, or funding line. Therefore, the phenomenon-driven nature of this thesis aligns with processes that can be organized in the pursuit of change, and not particular disciplinary views (Robinson, 2004).
3. **Socio-technical and socio-ecological systems conceptions provide the clearest points of entry for this work.** As discussed below, they conceptualize change at systems, and embed unsustainability as systemically rooted. Moreover, within both communities is a clear shift towards purposeful, emergent and deliberate change processes at micro-meso levels (Feola, 2015: Pereira et al., 2015; Loorbach et al., 2017).

Transitions and transformations can both be understood as change within complex systems. The systems central to transitions are often referred to as coupled socio-technical (ST) (Geels, 2002; Sovacool & Hess, 2017), whereas transformations are routinely concerned with coupled socio-ecological (SE) (Jerneck et al., 2011). ST transitions direct focus towards macroscopic change in systems via complex interplays between social, technological and institutional dynamics (Loorbach et al., 2017). This community draws historically from neo-institutional theory, evolutionary economics, science and technology and innovation studies (Geels, 2010). In contrast to framing technology as the central element and "*driver of change*", transitions adopt a systems perspective that recognizes the embeddedness of different ST configurations in society. Whilst the co-evolutionary nature of such elements are dynamic over time, ST transitions are characterised by high degrees of complexity, uncertainty and ambivalence (Andersson et al., 2014; Smith et al., 2005; Walker & Shove, 2007).

SE transformations, by contrast, reflect these characteristics in their connection to resilience, equilibrium, and adaption within complex adaptive systems. It draws from ecology, biology, systems theory and adaptive governance literature (Loorbach et all. 2017). Within SE systems, ecosystems undergo patterns of decay and renewal along panarchy cycles (Holling et al., 2002; Folke et al., 2010). Resilience denotes a state of equilibrium, as well as a property of bounce-back-ability within systems that are shaped by human-environment relationships (Olsson et al., 2014). These relationships pattern systems across different spatial and temporal scales. More recently, research in socio-ecological systems (SES) has begun to highlight how human-environment interactions are having irreversible, often unforeseeable, impacts on biophysical thresholds (Rockström et al., 2009). From a systems

perspective, the unravelling of environmental thresholds brings with it the likelihood of negative feedback loops within biophysical systems. The tensions associated with recognizing both the detrimental impact of human activity on planetary systems, and that such knowledge has proven insufficient to compel action, is summarized by Pereira et al (2015):

> *Understanding how the Earth system and human society function as a complex adaptive system requires us to use different language, referring to emerging and navigating transformations over managing, steering, or controlling transitions*
>
> *p. 2068*

As highlighted by Loorbach et al. (2017), both systems orientations share a view that systems can be understood as non-linear, emergent and complex. Both highlight the multi-phase and multi-level nature of interactions between social, technical and environmental spheres, with each having their own coupled interest. Relatedly, within both systems conceptualizations lie a distinction between processes that maintain stability, forms of dynamic equilibrium, and radical, disruptive change alternatives. These are expressed by way of parallel heuristics – S-Curve (Rotmans et al., 2001) and more recent X-curve dynamics in ST transitions (Hebinck et al., 2022) and panarchy cycles in SE transformations (Holling & Gunderson, 2002) – for understanding build-up and breakdown patterns within such systems. Given the equal emphasis on stability and obduracy, transitions and transformations have been historically understood as being gradual over time, occurring across multiple generations. On the one hand, systems of this kind exhibit a stability that is preserved by path-dependencies, lock-in effects and inertia (Unruh, 2000). On the other hand, possibilities for change within both can come from ruptures, discontinuities and punctuations that rapidly shift states.

4.3 Complex sustainability challenges

Moving forward, this thesis has chosen to concern itself with complex sustainability challenges. The reasons for this are twofold.

First, 'challenge' attempts to break free of the tyranny of categorizing reality as a series of problems and solutions. As described below, the categorization of unsustainability as a problem evokes a circular problem-solution logic, whereby a single solution can be arrived at. In the context of labs, approaching complex challenges in situations highlights the undefined, ill-structured and contingent nature of many sustainability issues. From a

learning perspective, such properties encourage learning orientations that attend to the phenomenon of framing (Ison, 2010; Lotz-Sisitka et al., 2015; Loorbach et al., 2017). Frames and framing processes are essential in approaching complex challenges, referred to as messes (Ackoff, 1973), problematic situations (Checkland & Poulter, 2010), matters of concern (Latour, 2004), or in-between issues (Vilsmaier & Lang, 2015; Ison, 2017).

Second, the contingent nature of sustainability challenges calls for explicit engagement in context. As a matter of praxis, this view stays true to challenges as situated, whose structure and meanings unfold through engagement. Given the multi-stakeholder nature of labs, as well as the focus on collaborative and integrative processes, how societal actors approach conversations around sustainability has consequences for the way in which knowledge *and, for & through* action are structured (van Kerkhoff & Lebel, 2006). In educational environments, challenges provide gravitating elements for learning situations that are challenge-driven, rather than problem-based[21]. These action-oriented considerations recognize the importance of step-0 processes as learning process (Horcea-Milcu et al., 2022; Ness, 2020), as well as the growing importance of develop capacities for framing and negotiating sustainability as an emergent property (Robinson, 2004).

Pervasive unsustainability can be understood as a series of complex challenges. Although individuals are quite attuned to managing the complicated nature of daily life, complex challenges arise from within complex systems. These challenges are distinctive from simple or complicated issues (Glouberman & Zimmerman, 2002). They are not owned by single actors, often spanning sectors, districts, or countries. Their dimensions cannot be understood through single experiences, and their consequences ripple unevenly over space and time. At the heart of it, complex challenges are attributable to the systemic nature of the task at hand, where ongoing socio-ecological and socio-technical unsustainabilties can be understood as symptoms of deeper root causes. They therefore recruit relational and emotional responses that transcend the individual, as they are perceived differently by many (Lönngren & Van Poeck, 2021; Engeström, 1987).

Complex challenges make it impossible to rely on blueprints or expert knowledge (Wals, 2015; Andersson et al., 2014) The reason for lies in the fact that they elude simplification and solving (Morin, 2008). Morin (2008) critiques the paradigm of simplicity, whereby "*to conceive of all objects and entities as closed leads to a vision of the world that is classificatory, analytical, reductionist, with linear causality*"(p.13). In response, they call for an epistemological reversal, where one must begin with the perception that systems are open,

[21] From a learning perspective, "*problem-solving and structuring are essentially reactive forms of learning. Both presuppose a context that presents the individual with a preset learning task. Learning is defined to exclude the possibility of finding or creating new contexts*"" (Engeström, 1987, p. 2).

and complexity leads to an essentially unknowable condition. Thus, sustainability challenges are entangled within open systems, arising in situations where uncertainty is latent. Moreover, their multi-causal and non-linear nature means that knowledge-to-act will always remain partial (Wals, 2015).

Given their complexity, uncertainty, situatedness and contextuality, such challenges do not adhere neatly to disciplinary knowledge; they do not invite singular definitions of a problem (Avelino & Grin, 2017; Morin, 2008; Gras, 2020). Yet systemic complexity is routinely reduced to issues of a simple or complicated nature (Andersson et al., 2014). The limitations associated with reducing complexity in sustainability challenges are becoming more documented in fields such as mobility transitions, energy transitions and education. These limitations include: (1) responding to symptoms rather than causes, (2) manufacturing closure in open-ended systems[22], (3) assuming control and resolution, (4) parsimony (Gras et al., 2020; Lönngren et al., 2017). Bardwell (1991) notes that environmental problem-solving agendas are susceptible to: (1) solving the wrong problem, (2) stating the problem so it cannot be solved, (3) solving a solution, (4) stating problems too generally and (5) trying to get agreement on the solution before there is agreement on the problem.

Interestingly, the above realizations are not necessarily new – Rittel and Webber (1973) famously defined wicked problems almost 50 years ago. From the tendencies discussed above – *to simplify, to reduce, to assume solution* – emerges a fourth that is increasingly problematic in navigating change towards sustainability. As argued by Gras et al. (2020) and Meadows (2008), the reduction of complex issues to simple cause-effect-response chains is convenient for existing institutions and ways of governing. Political decision makers tend to favour technical, incremental, end-of-pipe solutions over deeper points of leverage (Meadows, 2008; Abson et al., 2017; Meadowcroft, 2009; Avelino & Grin, 2017). Techno-managerial solutions routinely displace, prolong, reduce, or shift the symptoms associated with an issue[23]. From a systems perspective, Meadows (2008) compares this approach to

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[22] Mingers (2014) notes the difference between ontologically open systems and the forms of manufactured closure that experimental methods strive for within clinical lab settings. Here, he states: "*Social systems are inherently interactive and open. While the same is true for natural systems, it is the case that they can be artificially closed or controlled in the laboratory, and this indeed is the principal reason for experiments. This however is not (generally) possible in social systems. The main effect is that it is difficult to test theories, since predicted effects may or may not occur depending on a multitude of factors. This point focuses attention on a theory's explanatory rather than predictive power.*" (p. 34

[23] This phenomenon appears across various research strands as rebound effects or unintended feedbacks. Meadows (2008) attributes rebound effects and unintended feedbacks as consequences of responding to events within systems, rather than tackling root causes. Within transitions studies, dead-end incrementalism is a form of solutionism that is "*insufficient because these are not able to tackle system failures underlying persistent problems in an adequate manner, leading to suboptimal solutions.*" (Kemp et al., 2007). Carton (2019) critiques negative emissions narratives as they promise "temporal fixes" that delay action in the present,

fighting fires, where solutions to problems in the present produce both similar and diverse problems in the future, which in turn require more solutions:

> *If the intervention is a drug, you become addicted. The more you are sucked into an addictive action, the more you are sucked into it again […] Addiction is finding a quick and dirty solution to the symptom of the problem, which prevents or distracts one from the harder and longer-term task of solving the real problem. Addictive policies are insidious, because they are so easy to sell, so simple to fall for.*
>
> *Meadows, 2008, p. 133*

To take a contemporary example, conversations around sustainability tend to be reduced to that of climate change (Hulme, 2011), and marked by reactive approaches such as resilience that respond to the various dimensions of sustainability by adapting to impacts (Loring, 2020; Olsson et al., 2015). Of course, climate change adaptation is crucial in responding to the consequences of global warming. However, climate reductionism, when combined with determinism, reduces to climate an array of relations between social and ecological issues (Hulme, 2011). In a similar vein, environmental geographies have reacted strongly to how responding to extreme weather events perpetuate, rather than resolve, the roots of complex challenges:

> *Far from flattening the social differences, disaster reconstruction invariably cuts deeper the ruts and grooves of social oppression and exploitation.*
>
> *Smith, 2006, p. 4*

Relatedly, in education, Kuntz and Petrovic (2018) notes that dominant attempts to realign educational systems tend to do so through the conservative and reactionary gaze where: "*politicians proclaim a need to fix education through rigidly aligning schooling with the processes and practices of the past (thereby avoiding any possibility for a radical future), seeking static formations of knowledge, all in the name of expanding the globalized neoliberal project*" (p. 66). From a directional perspective, responses such as those outlined above limit the future to that of patching up the present to various degrees (Bregman, 2018), limiting expansive possibility (Hulme, 2011).

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and Mattioli et al. (2020) outlines road expansions as an example of ineffective spatial fixes that showcase firefighting and dead-end incrementalism in mobility systems.

4.4 Governing and navigating change

Previous focus has been placed on providing a structured examination of the surrounding dynamics and mechanisms of change within systems (Geels, 2002; Schot, 1998; Holling & Gunderson, 2002). In addition to understanding *how* and *why* systems have changed *in the past*, a purposeful approach implies that qualitative change within open systems *should be sought into the future*. Feola (2015) highlights that there has been a recent growth towards transformative change-in-the-making. Given their strong process orientations:

> *The study of sustainability transitions is not only about studying how things 'are' at a specific point in time, nor only about how they 'ought to be' in the future. Most crucially, it is (also) about understanding how things can be, now, in the near future, and in the long-term. In that light, the challenge is to analyse phenomena in terms of transformative potential, i.e. the capacity to change what 'is' in to that which is believed 'ought to be'. In its broadest sense, transition research by its nature is also about studying how things can be, and […] trying to operationalise a 'can-be-philosophy' in a political context dominated by 'is-versus-ought' debates.*
>
> *Avelino and Grin, 2017, p. 22*

4.4.1 Reflexive governance

Transitions and transformation research has been recently shaped by a "reflexive" turn of sorts, shifting emphasis towards alternative modes of governance when entering uncertain terrain (Köhler et al., 2019; Loorbach et al., 2017; Smith et al., 2005; Loorbach, 2007; Voss & Kemp, 2005; Rotmans, et al., 2001). Rather than understanding historical change, or controlling change forwards, processes are interested in the *reflexive governance* as a way of navigating change. This shift has brought with it an inclusive set of ordering theories, methodologies and philosophies of science (Sovacool & Hess, 2017). Respective approaches span the descriptive and the purposeful (Feola, 2015); the distanced and the embedded (Voss & Kemp, 2005); the qualitative and the quantitative (Sovacool et al., 2018). These developments imply that it is possible to influence transitions and transformations, rather than respond to them.

Reflexive governance concerns the coordination of systems change towards collective normative goals. Its 'reflexive' character draws from both complexity sciences, reflexive modernization (Beck, 1994) and systems thinking. Its central premise is that mainstream

governance paradigms are generating problems in society that disproportionately undermine attempts to solve them (Voss & Kemp, 2005). It situates the problem at the level of a governing model obsessed with rational, reductive, problem-solving. Reflexive governance then, signals an alternative, capable both of framing such challenges and mobilizing around them. Crucially, reflexive governance assumes that such governing takes place within systems that are co-evolving. With feedbacks between process and system, as well as within process, 2nd-order reflexivity attempts to anticipate, modulate and learn amidst uncertainty (Meadowcroft, 2009; Stirling, 2016). Here *"reflexivity is not so much a quality situated within any given body of governance knowledge, but about it"* (Stirling, 2016, p. 20). The ambitious task of reflexive governance is therefore twofold: to simultaneously (1) orchestrate the governance of complex socio-technical-ecological systems towards sustainability, and (2) to assume a continuously reflexive stance, acknowledging the highly ambivalent and uncertain inherent in such transitions. The bending back of action and direction onto one another within ongoing transformations is a hallmark of reflexivity, where:

> *A characteristic of reflexive governance is that it is concerned with itself – its working within the context of societal development and the specific potential and limitations that result from it. It understands itself to be part of the dynamics which are governed.*
>
> *Voss & Kemp, 2005, p. 8*

Loorbach et al. (2017) contends that despite the above differences between ST and SES change, purposeful and deliberate change processes share interest in *reflexively governing change*. Here, they share five commonalities:

1. **Systems change processes concern multiple actors simultaneously.** Given that transitions have historically over-favoured technical explanations of change (Meadowcroft, 2009), and transformations have historically over-favoured the environmental and adaptive natures of change (Pereira et al., 2015), deliberate change from both communities casts attention to role of individuals and relationships (West et al., 2020). This includes actively engaging with power (Meadowcroft, 2009), agency and capacity to act, as well as matters of justice in systems change (Williams & Doyon, 2020).
2. **Given the contested nature of systems change, there is a growing need to develop approaches that support shared and collective understanding.** Reflexive governance is both normative and interactive, meaning that it shifts the focus of governing – already implying decentralized decision making (Marinetto, 2007) – away from external systems to be steered. It conceives of systems change as both political

and agential, where agency is scattered across multiples levels and sectors (Elzen et al., 2004; Iuel-Stissing et al., 2020). This contestedness signals that sustainability challenges are perceived differently, lived differently, and are imbued with multiple perspectives. Systems thinking provides a re-entry into sustainability challenges as symptoms of complex systems, rather than empirical events in society. It additional promotes approaches that attend to undesirable systems configurations, exnovation and destabilization processes (Meadowcroft, 2009).

3. **The temporalities associated with purposeful change mean that frameworks for historically understanding change are insufficient for engaging with transitions-in-the-making** (Hebinck et al., 2022). In short, they provide little guidance for the collective construction of multiple future alternatives. Engaging with purposeful change is attracting attention towards methodologies for radical and plural futuring, as well as exploring change pathways along short-medium-long term horizons (Muiderman et al., 2020).
4. **Given the unstructured and unfamiliar nature of navigating change forwards, transitions and transformations are unavoidably experimental.** Experimental practices and processes provide points of entry into systems characterized by complexity. Moreover, their forms and scale often imply protective spaces, with higher reflexive capacities (Morin, 2008), that can function as microcosms of change into the future (Engeström, 1987; Smith & Raven, 2012). Increasingly, these forms of experimentation have shifted from technical experiments towards social and organizational modes (Bennett et al. 2016). As highlighted in section 3.2, experimentation of this kind focuses on testing, prototyping and rapidly organizing amidst complexity in a contingent manner.
5. **Transitions and transformations are ultimately matters of learning. Transformations into the future carry high degrees of uncertainty, as well as the need for new forms of knowledge and action.** Given its experimental character, continuous, reflexive and experiential learning processes are central. These dimensions highlight the emotional, personal and relational implications of navigating systems change (Vogel & O'Brien, 2022). Learning orientations attend to the possibilities raised by collectively exploring alternative and desirable futures (Hoffman et al., 2021; Muiderman et al., 2020), as well as the need to unlearn, let go of, and grapple with trade-offs associated with systems change (Robinson, 1988; van Oers et al., 2021).

4.4.2 Transdisciplinarity and transformative science

Because navigating change carries a heightened sense of complexity alongside an acknowledgement of multi-perspectivity within systems, reflexive strategies routinely hold inter-, and transdisciplinary (ID, TD) stances (Loorbach et al., 2017). TD is associated with co-production which is irreducible to a discipline or actor set (Abson et al., 2017; Brandt et al., 2013; Lang et al., 2012; Polk, 2014)[24]. With roots in ID and sustainability science, TD presents a normative, action-oriented approach to science in society (Lang et al., 2012). It follows post-normal science (Funtowicz & Ravetz, 1993) in the pursuit of socially robust knowledge towards societal change (Miller et al., 2014). Post-Normal science concerns itself with "*bridging the gap between science and practice to more effectively use science to capture and solve current social and environmental problems*" (Polk, 2014, p. 440).

Whereas in ID the boundaries between science and society remain largely upheld, TD marks a movement beyond knowledge asymmetry. It also carries recent ambitions of the transformation of science system. Therefore, TD knowledge practices seek outwards and inwards impact. TD research can be both integrative and agonistic[25], in a similar fashion to more recent conceptions of ID (Barry et al. 2008). It can also be stylistic, conceptual, philosophical or practical in nature (Mitchell et al., 2015).

While several scholars have worked towards formalizing TD practices by recognizing the need for socially robust knowledge, earlier forms of TD fell short of challenging the assumption that scientific knowledge holds a central role. Sustainability challenges may themselves emerge from situations of concern and everyday multi-actor collaborations. In recent years therefore, the term has been evolving to include both are science-driven or issue-driven variants (Robinson, 2004). TD can therefore relate to the act of establishing research processes (Lang et al., 2012); the act of accompanying ongoing efforts by non-scientific stakeholders (Alonso-Yanez et al. 2019); the act of accompanying TD research projects (Lang et al., 2012).

Ross and Mitchell (2018) note how these spectrums also appear from within TD, illustrating how 'strong' forms of TD can stretch and rupture the meaning systems that have stabilized

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[24] According to Robinson (2008), an academic definition of TD is "*knowledge unity is the highest form of integration between disciplines",* whereas a stakeholder definition of TD *"includes knowledge and expertise from both academic and non-academic actors and stakeholders*" (p. 73)

[25] Influenced by the work of Mouffe (2005), Barry et al (2008) points to multiple logics of ID-TD approaches. Whereas one logic concerns the integration principle, agonistic logics refer to transcendental views of knowledge and action that may in fact seek to destabilise problematic knowledge practices. Rather than integrating from different disciplines or knowledge forms in order to create hybrids, agonism seeks a commitment to radical ontological and epistemic shifts that are plural.

through Cartesian-Newtonian logics (Table 1). These distinctions illustrate how deeper forms of TD depart from conventional paradigmatic claims that scientific knowledge is objective and value-free (Stirling, 2010; van Kerkhoff & Lebel, 2006), the systems and sub-systems within which the natural and social exist are commensurable (Olsson & Jerneck, 2018), graspable (Stirling, 2010) and plannable (Avelino et al., 2016; Loorbach, 2010; Shove & Walker, 2007), and that science-technology-society relations are deterministic in nature (Cash et al., 2003; Scoones et al., 2015). Many of these claims have contributed to the methodological bases for reflexive governance strategies (Hölscher et al., 2021). A growing emphasis has been placed on "step-0" and joint framing processes (Horcea-Milcu et al., 2022), as well as conceptions of slowness and self-care (Sellberg et al., 2021).

	Cartesian-Newtonian discourse	Strong Transdisciplinarity
Cosmology	Universe as machine Reductionism as instrument Prediction Parsimony and simplicity Preservation of disciplinarity	Universe as living, self-organizing realm Change as continual Prediction as impossible Erosion of discipline
Ontology	Human rationality Mind-body-soul-nature-world separation Domination and control	Laminated systems Deep, radical interconnection Selves in systems
Epistemology	Fragmented knowledge Boundary protection Profit over planet	Multiple knowledge forms Embodied, actionable, collective, loving knowledge
Axiology	Ends over means or means over ends False dichotomies. i.e., Fact-value Technocratic mindsets	Collapse of false dichotomies Recognition of subjectivity as ethics
Anthropology	Human-nature disconnect Exploitation of environment Binary + authoritarianism	More-than-human Care for living world
Social vision	Growth paradigm	Flourishing, hope, liberation

Table 1: Tenets of strong TD. Source: Ross and Mitchell (2018)

5 Learning for sustainability transitions and transformations

It's not a package tied with string,
or a machine with precise instructions.
It doesn't obey rules or masters.

No-one can patent it though many have tried.
It's never been captured and bottled,
or dissected, defined, or delivered.

It has many colours and scents,
many flavours and textures,
it can speak in every language.

And every time people tell a story
and others give their whole selves
to listening, it can happen.

And every time someone asks real questions
and honours unexpected answers
then acts on them, it happens.

It's out there in the field, waiting for you,
like a juicy red fruit or a pale blue flower, or the raindrop
you can catch in your hand because you watched as it fell.
Tracey Martin

Of relevance in this thesis is the view *that transitions and transformations are ultimately matters of learning* (van Mierlo & Beers, 2018; Van Poeck et al., 2018). I lean on theorizations of learning as a fundamental mechanism of sustainability transitions and transformations, motivating the importance to collectively transgress established ways of engaging with sustainability. Given their situatedness, labs can be understood *as certain kinds of spaces.* As part of these conversations, learning can be traced to an eclectic mix of literature from socio-technical experimentation (Brown et al., 2003), strategic niche management (Raven et al., 2010; van den Bosch & Rotmans, 2008), social/reflexive governance literature (Collins & Ison,

2009; Voss & Kemp, 2005), education for sustainable development (ESD) (Holmberg, 2014; Wals, 2015; Lotz-Sisitka et al., 2015) and adaptive and collaborative governance (Reed, 2008; Ison et al., 2015)

5.1 Social, transformative, transgressive learning

As an initial discussion into the learning, I turn to the work of Sfard (1998). Here, the author presents metaphors of *acquisition* and *participation* as frames for learning as a phenomenon. The *acquisition metaphor* is associated with the internal movement of knowledge, guided by the "learner" as a central recipient of knowledge. It belongs to a series of research traditions that hold the locus of learning to be internally held, rather than relationally distributed. These include cognitive, psychological and behaviouralist approaches to learning. Constructivist and interpretivist perspectives on learning also fall under this banner, indicating that the constructed nature of knowledge remains bound to individuals and context remains bracketed.

Learning as participation, in contrast, extends the remit of what learning is, who learning relates to and how learning unfolds. The participation metaphor makes room for impermanence as one moves from internal to external planes of a situation. Moreover, the emphasis on participation as an action invites conceptual and practical threads around relationality of selves within systems (Sfard, 1998; Senge, 2015). Learning as participation marks the moment where that which would formally be considered context, such as community development, horizontal relations, intersubjectivity, all become internal to learning.

In sustainability transitions and transformations, social learning appears as both theory and practice. Its appeal lies in how it caters to the multi-stakeholder changes that are advocated from within both communities. It is regularly connected to broader orientations regarding systems change in times of uncertainty, including transformative, transgressive and expansive learning (Boström et al., 2018; Wals, 2015; Lotz-Sisitka et al., 2015). In times of transformation:

> *Social learning emerges when individuals and groups employ dialogue to collectively problem-solve; surface assumptions through reflexivity; and use experimentation, improvisation and adaptation in their initiation of novel approaches.*
>
> *Slater and Robinson, 2020, p. 3*

Depending on its application, social learning can be seen as an input, mechanism, process or outcome of multi-stakeholder processes (Armitage, 2008; Reed, 2010). When approaching wicked sustainability challenges, Ison (2015) finds that social learning can mean: (1) the negotiation of purpose, success and ways of knowledge that build relational capital, (2) the process of co-creation of knowledge, (3) an emergent property of the process to transform a system, or (4) a governance mechanism relevant for complex sustainability challenges. This range of situations therefore draws from a host of learning theories aimed at emancipation and systemic action, such as transgressive social learning (Lotz-Sisitka et al., 2016) and expansive learning (Engeström, 1987).

Ideas around transgression in education have existed in the work of Bell Hooks (1994) as the movement beyond accepted boundaries that reinforce oppression. Within transitions and transformations, transgression is tightly tied to processes of social learning. Transgressive social learning is

> *A form of transformative learning that intentionally generates critical thinking and collective agency and praxis that directly and explicitly challenges those aspect of society that have become normalized, but which require challenging for substantive sustainability transformations to emerge (e.g., colonial practice or epistemology, gender and race relations, social exclusion, didactical contracts, environmental injustice).*
>
> *Lotz-Sisitka et al., 2016, p. 51.*

Transgressive learning illuminates the contested nature of sustainability challenges, particularly when organized around knowledge and action boundaries. Here, learning by expanding and "learning what is not yet there" occurs through the construction and resolution of contradictions that appear in existing organisational practices (Engeström, 1987). Transgression points towards learning processes that signal a heightened sensitivity towards boundaries between stakeholders, sectors and perspectives, as well as the deeply held assumptions and constraints that each may hold. It sees transformations as a matter of meaningful agonism, where sustainable futures require both creation and struggle. As highlighted by Lotz-Sisitka et al. (2015):

> *The transformative, transgressive forms of learning described all require engaged forms of pedagogy that involve multi-voiced engagement with multiple actors. They also have an emphasis on co-learning, cognitive justice, and the formation and development of individual and systemic agency. Their focus is the public and the personal good.*
>
> *p. 78*

To transgress is *active* and *purposeful*; it articulates a frame for radical systems change that where agency expressions go against the grain. In addition, transgressive learning theories draw from social learning in better understanding a mode of resistance that is relational in nature. Wals (2015) draws parallels between social, transformative, and transgressive learning by way of shared descriptors:

- They consider learning as *more than merely knowledge-based*,
- They maintain that *the quality of interaction* with others and of the environment in which learning takes place as crucial,
- They focus on *existentially relevant or 'real' issues* essential for engaging learners,
- They view learning as inevitably *TD and even 'trans-perspectival'* in that it *cannot be captured by a single discipline* or by any single perspective,
- They regard *indeterminacy* a *central feature* of the learning process in that it is *not and cannot be known exactly what will be learnt ahead of time* and that learning goals are likely to shift as learning progresses,
- They consider such learning as *cross-boundary* in nature in that it *cannot* be *confined to the dominant structures and spaces* that have shaped education for centuries.
- They require the development of *agency*, *action competence* and *disruptive capacity*.

5.2 Systems inquiry as learning

Reflexive governance approaches inform their work from complexity sciences to learn despite uncertainty (Ison, 2010; Avelino & Grin, 2017). Their process-based nature means that governing change involves the exploration of direction, purpose, transformative potential and capacities to act (Köhler et al., 2019; Bai et al. 2016). Situated engagement of this kind is reflective of an action-oriented approach to research (Loorbach, 2007; Scholz, 2017), where "*[…]sustainability must become recognized as a contested, discursive resource for learning – a boundary object – that facilitates argument about diverse pathways to different futures*" (Leach et al., 2010, p.114). Central to these processes is the view that governing concerns the very systems that are under inquiry. They accept that systems are complex but advocate for process-based engagement with complexity in context, with an emphasis on learning. In the words of Boulton et al. (2015):

> *A complexity worldview sees the world as essentially interconnected, and rich with forms and patterns that have been shaped by history and context. A complexity worldview reminds us of limits to certainty, it*

emphasizes that things are in a continual process of 'becoming' and that there is potential for startlingly new futures where what emerges can be unexpected and astonishing.

p. 1

Systemic inquiry brings with it meta-methodologies, such as systemic interventionism[26,27], critical systems heuristics, systemic practice, and soft systems methodology. (Midgley, 2000; Ulrich, 2003; Ison, 2010, and Checkland, 1989). Although products of emergent practices elsewhere, with their own epistemic and ontological foundations, these approaches enrich the systems conceptualizations implied by transitions and transformations. They do this by way of theoretically informed meta-methodologies that bridge both analytical conceptions of complex systems with participatory processes (Abson et al., 2017; Grin, 2020).

Systems thinkers such as Checkland (2000), Ison (2010) and Midgley (2000) recognized that systemic inquiry would benefit from a more pluralistic and reflexive orientation. They were part of a paradigm shift in that had previously been rooted in operations management and first-order cybernetics, and that was struggling with the ill-structured organizational and social issues (Ison, 2010). For Checkland (2000), the ambition of systems practice was to introduce holistic approaches to systems rather than those dominated by reductionism. In contrast to the hard systems focus on as material reality as an ontology (with clear and mathematical understandings of causality and wholeness), soft systems introduced a systemic process of inquiry (Checkland, 2000[28], see Table 2). This movement brought with it core assumptions:

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[26] The term intervention can be seen as a boundary object within this thesis. Within more classical sciences, interventions are located at the level of experimental method. It signals a movement made by a subject on an object, a form of "stepping into the natural order of things through the manipulation of a certain series of events". Here, intervention is associated with observation. In educational sciences, interventions resonate with the practice of adjusting education at the level of measure, in search of effect. It ranges from the notion of intervening as an educator from the outside, to interventions as collective responses within educational settings (Danermark et al. 2005). Evidence-driven approaches to education may for example focus on educational interventions that seek improvement in educational quality through an interest in most effective intervention. Within systems thinking Donella Meadows (2008) refers to places to intervene within a system, and Gerald Midgely (2000) refers to interventionism as a purposeful action by an agent to create change.

[27] In positivist accounts of systems thinking, there was an enduring sentiment that the act of observation sat outside of the system in focus. The dominant idea was that robust systems science maintained a level of distance from their systems of inquiry. Inspired by 2nd order cybernetics (Von Foerster, 1979), action-research (Lewin, 1946) and critical systems thinking (Ulrich, 2003) systemic interventionism builds upon the idea of systems science as purposeful intervention. Midgley defines interventionism as "*purposeful action by an agent to create change" (2000, p. 156). Systemic interventionism, then, can be understood as action taken in relation to reflection upon boundaries*[27], (Midgley, 2000).

[28] According to Checkland (2000), "*The world is taken to be complex, problematical, mysterious. However, our coping with it, the process of inquiry into it, it is assumed, can itself be organized as a learning system. Thus,*

- A movement from problems "*out there",* to people *trying to act* in a situation
- That the goals and purposes of systems *have blurry definitions*, which are subject to formulation in context
- The growing importance of *worldviews and belief systems* in affecting the *constructions of issues* and eventual responses
- Systemic interventionism is a meaningful way to *develop actionable* knowledge *in systems*, rather than *analytical knowledge about systems*

Soft systems thinking outlines a methodology for facilitating processes that catalyse collective discussion on what a system is, whose values count in the construction of meaning (Jackson, 2016), how it can be related, and which change/intervention is desirable. This shift has been meaningful for several reasons that relevant for entrance into complex challenges. First, it welcomed a new vocabulary for seeing certain messy problems and complex challenges as un-engineerable. Systems thinking approaches began to seem well-suited for challenges that are social, as well as coupled understandings of systems as socio-technical and socio-ecological. Second, soft systems thinking decentred ontology in favour of epistemology. It achieved this by treating real-world problems as perceived situations. Here, proponents for action-oriented approaches to systems change highlighted the common importance of boundary construction[29] (Ulrich, 2003 and Churchman, 1970). Third, it situated learning about systems directly within the processes that may be required for improving problematic situations[30]. This process-based approach emphasises learning in situation, where knowledge and action reciprocate through cycles of inquiry).

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the use of the word `system' is no longer applied to the world, it is instead applied to the process of our dealing with the world" (p. 17).

[29] Whether constructing optimization models on energy and electricity systems, identifying resource flows and environmental impacts of current or prospective technologies, or attempting to identify leverage points for real-world sustainability challenges through experimentation, any systems approach is constituted by both boundaries and framing, neither of which are absent from ethical considerations nor value judgements.

[30] As mentioned, such tensions are by no means new, with their own expressions in the debates around general systems theory (Boulding, 1956). One only needs to turn to the work of Ulrich on critical systems heuristics (2003), of Midgley on boundary critique and systemic interventions (2000) and of Churchman (1968) on the relation between values, ethics, and the "analyst" in constructing systems. Such arguments contend that decisions made are not value free and can have significant implications for the types of systems included, as well as the conclusions that can be drawn. More recently, the sustainability pathways approach has recognised that systems boundaries, as well as their particular elements, are expressed by different stakeholders in different contexts at different times (Leach et al., 2010). These system boundaries are often embodied either explicitly or implicitly by the choice of problems that are highlighted, the solutions which are pursued and the forms of knowledge which are prioritized/assumed.

Hard systems thinking tradition	Soft systems thinking tradition
Oriented to goal seeking	Oriented to learning
Assumes the world contains systems that can be engineered	Assumes the world is problematical but can be explored by using system models
Assumes system models to be models of the world (ontologies)	Assumes system models to be intellectual constructs (epistemologies)
Talks the language of 'problem' and 'solutions'	Talks the language of 'issues' and 'accommodations'
Assumes that there is a right answer	Does not produce the final answers and accepts that inquiry is never-ending
May lose touch with aspects beyond the logic of the problem situation	Remains aware that there are dimensions of the situation to which linear logic does not apply

Table 2: Distinctions between hard and soft systems thinking traditions. Source: Checkland (2000)

5.3 Labs as learning spaces

As highlighted in the introduction, it is helpful to view labs as *a certain kind of space.* Recent work has investigated the learning-orientations of labs (Larsson & Holmberg, 2018; McCrory, 2016; Singer-Brodowski et al., 2018; Wanner et al., 2018; Lumosi et al. 2019). In terms of their relation to sustainable futures, labs are claimed to be settings where radical alternatives can be co-produced in limited space and time (Loorbach et al., 2017). Aside from the existing socio-technical label of the niche, turning to learning sciences and geographies can provide a point of entry for understanding labs as a space oriented towards learning.

The recent spatial and "geographical turn" in sustainability transitions and transformations has directed attention towards labs as learning spaces[31]. Here, "*they gather a variety of actors that are brought together by a sustainability challenge as a common matter of concern"* (Van Poeck et al., 2018, p. 302). This space is neither *"the passive locus of social relations",* nor a container for things to run according to script (Elden, 2007). Rather, learning spaces expand possibility for spaces to be produced in and through social contexts (Lefebvre,1991, Soja, 1989).

[31] Van Poeck et al. (2018) draw attention to the importance of labs and experiments as learning spaces, described as learning environments with explicit orientations towards learning by doing, experimentation and exploration.

As suggested in Section 2.3, labs as learning spaces are situated at the in-between. Vilsmaier & Lang (2015) offer the view of in-between spaces as *"places that do not belong exclusively to one person but are shared and used by many people as a common good. [. . .] As a place of complex resources shared, they reflect community and collectivity, but at the same time they lay outside and challenge many norms of 'society'* "(p. 51). In-betweenness highlights how labs often approach situations where distributed agency exists (Iuel-Stissing et al. 2020). It signifies the paradoxical need to bound labs, where "their existence and their extinction are constitutive of in-between spaces." (Vilsmaier & Lang, 2015). Understanding labs as liminal spaces points towards processes of both unlearning and learning associated with experimentation at the in-between.

Liminality centres around a "wavering between two worlds" (Keefer, 2015), where available epistemic frames and value positions become threatened. Rather than focusing on the hybrid nature of products, services of new ways of doing, liminality brackets output and attends to in-between spaces as working at the thresholds. For example, in the face of challenges that are post-normal in quality, existing disciplinary positions seem incompatible with the task at hand. Transformative and transgressive learning suggest liminality via frames of references or through transgression between knowledge systems, and social learning expresses liminality movements from "me" to "we" within learning environments (Lotz-Sisitka et al., 2015). Rather than undesirable, deviance and dissonance encourage the redesign of learning objects, emergent forms of learning from borders and fringes, and redirected processes for moving forward (Engle, 2006; Engeström, 1987).

As in-between spaces, labs might be understood as a provisional 'thinness' to their form and content (Sheehy, 2004). When situated in educational contexts, this operates in contrast to the dominance of 'thick' classrooms. When in societal contexts, thick spaces may be visible through pre-defined processes, ex-ante evaluations and set roles for relating. Thickness constrains the possibility for negotiation and experimentation, creating cramped material, affective and cognitive conditions. It limits how different actors navigate multiple temporalities, how they navigate their personal histories with a complex present, and how they explore "what has not happened and may never happen" (Massumi, 2007). Thinness, on the other hand, invokes the notion of incompleteness in content, curriculum and output. provides a basis for co-producing thick presents and desirable futures with student-teachers, teacher-students and research-society as co-learners (Poli, 2011; Freire, 1970; Leander et al., 2010). In addition, thin learning spaces bring an increased possibility that multiple trajectories and pathways are possible, promoting more critical directional work.

Summary of background

Through chapters 3, 4 and 5, I have broadly entered the landscape of literature relevant for sustainability-oriented labs in real-world contexts. From this background reading, the following points form a basis for proceeding with research phases in this thesis.

First, the laboratory provides a timely research-practice object in transitions and transformations (chapter 3). Having developed into a heralded site of knowledge production, the laboratory prioritizes instrumental knowledge and mechanistic understandings of change. In response to calls for robust science-society interactions, labs in the real-world reflect a renewed language and practices in open social systems. By inflecting the conventional notions of the lab, labs in real-world contexts emphasize a more inclusive physical and discursive space where claims to knowledge can occur.

Second, I approach sustainability transitions and transformations from a *challenge-oriented perspective, with an interest in governing and navigating change*. *(chapter* 4*).* Transitions and transformations motivate change of a systems nature. Both have benefited from cross-fertilization by virtue of joint interests in reflexive governance. Reflexive governance views the development of change processes as internal to the development of systems. It therefore advocates for processes that harness the *multi-actor, systemic, futures-focused, experimental, and learning-orientated* nature of transformative change. Reflexive governance nurtures ID-TD methodologies for actionable knowledge, implying radical philosophical and axiological directions when governing change. These directions include beginning beyond discipline, viewing reality as one of deep systemic interconnectedness, embracing plural knowledge forms that connect humans to eachother and to natural realms, and conceiving of progress beyond growth. This thesis specifies a *challenge-orientation*, given its interest in challenge-framing, experimentation and place-making.

Third, that *I lean on learning as a fundamental mechanism of change*, (chapter 5) motivating the importance of transforming and transgressing established ways of acting around sustainability. Governing transitions and transformations require learning orientations that are social, transformative and transgressive. Systemically, challenges provide learning situations with points of entry into the complexity of unsustainability. Moreover, sustainability-oriented labs can be broadly understood as *certain kinds* of learning spaces. They exist in between sectors, organizations, science and society. They gravitate around authentic societal issues, inviting for the experimental and unfamiliar trajectories that systems change indicates. Moreover, these learning orientations accommodate expansivity and growth in-and-through connection.

6 Research strategy

I consider a tree.

I can look on it as a picture: stiff column in a shock of light, or splash of green shot with the delicate blue and silver of the background.

I can perceive it as movement: flowing veins on clinging, pressing pith, suck of the roots, breathing of the leaves, ceaseless commerce with earth and air—and the obscure growth itself.

I can classify it in a species and study it as a type in its structure and mode of life.

I can subdue its actual presence and from so sternly that I recognize it only as an expression of law—of the laws in accordance with which a constant opposition of forces is continually adjusted, or of those in accordance with which the component substances mingle and separate.

I can dissipate it and perpetuate it in number, in pure numerical relation.

In all this the tree remains my object, occupies space and time, and has its nature and constitution.

It can, however, also come about, if I have both will and grace, that in considering the tree I become bound up in relation to it. The tree is now no longer It. I have been seized by the power of exclusiveness.

Buber, 2008, p. 7

As a multi-referential object (Ardoino, 1993), there is no shortage of ways to study labs in real-world contexts. They can be studied from afar, or as an object of study that concerns a research community. The lab can be grouped together with comparability in mind, or with an eye on specificity of insight. It can provide an empirical backdrop for conceptual or theoretical exploration. The lab can analytically be understood in advance of its inception, in the making, retrospectively, or prospectively. Alternatively, the lab can be engaged with "from within". One may focus on design, development, facilitation, or evaluation. Here, equal emphasis might be placed on not only what the lab is, but what it does; researchers entangled in a space that is both practical and conceptual in nature, employing an action-oriented role alongside different stakeholder constellations. Overlap may also exist between these components, with fuzzy boundaries between research and practice.

As introduced in chapter 1, the overarching aim of this thesis is to *investigate how sustainability-oriented labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformations*[32]. It relies upon four complementary research questions:

1. How might sustainability-oriented labs in real-world contexts be understood?
2. As an educational lab, how does Challenge Lab (C-lab) organize around sustainability challenges, and how do such challenges unfold?
3. In which ways do sustainability-oriented labs engage with sustainability, and how can they be categorized?
4. What is the capacity of evaluation practices as a tool for sustainability-oriented labs?

Below, I outline an account of my research strategy, before broadly covering the threads of three research phases in my PhD. This includes my ontological, epistemological, methodological, empirical and analytical choices (Figure 3).

6.1 Critical Realism as research philosophy

> *Making a choice of one epistemological position or another in each context is not an act of discarding or deciding against the other position – it is an act of being aware of the choice being made and taking responsibility for it… Being epistemologically aware opens up more choices for action.*
>
> *Schlindwein & Ison, 2004, p. 30*

My thesis is underlaboured by a critical realist philosophy of science. Critical realism (CR) as a meta-theory is traceable to the work of Roy Bhaskar (2008). At the risk of summarizing, it emerged from deep thought by Bhaskar and others regarding the limits to social constructivism and empirical realism in the 1980s. On the one hand, CR admonished empirical realism for how it fell victim to the epistemic fallacy by conflating ontology – that

[32] The papers that I have published, equivalent to "*my research*", comprise one of three formal activities in my doctoral journey. I have been shaped continuously in the form of teaching, and the courses that I take as a PhD. When outlining articles, I switch between "*I*" and "*We*" depending on whether my intention is descriptive or reflective. "*We*" recognizes the highly collaborate nature of all research phases, whereby both research and education efforts have been underpinned by collective work. When discussing findings and synthesizing this thesis, I write mostly in 1st person to reflect that synthesis sits above research phases and connects to this PhD thesis.

is, the way the world is – with epistemology – that is, our knowledge of the world. In critical realist terms, although empirical realism implies a realist ontology, it collapses three levels of being in the world into one, flattening reality[33]. On the other hand, CR emerged out of a critique of the weakness of social constructivism in moving beyond construction. Via immanent critique of both approaches, critical realism proposes a philosophy of science that combines ontological realism, epistemological relativism, and judgemental rationalism.

As a realist ontology, CR proposes an ontology that is distinct from epistemology. That is to say, it asserts that an objective world exists that is distinct from our attempts to approach and know it. Systemically, this world is open, not closed; it is stratified and layered; and the tasks and knowledge of science exist within. CR rejects atomistic notions of causality, in favour of a holism. With regards to its stratified nature, reality is then distinctive by way of three nested domains: the empirical, the actual and the real. As ontological realists with an interest in the stratified ontology and our knowledge of it, CR endeavours to look "behind" or "below" empirically observable events. Here:

> *The empirical domain includes that which we can observe – things that happen and exist according to our immediate experience. The actual domain is a broader one and refers to that which transpires independently of the researcher or any other observer who might record it. Finally, the domain of the real includes those mechanisms that are productive of different events and other 'surface phenomena'.*
>
> *Alvesson & Sköldberg, 2017, p. 40*

Epistemically then, CR approaches practical research by asking the question: *What must reality be like to make the existence of science possible?* It resolves this question by holding that knowledge of the world sits within the world but is irreducible to it. Speaking to the task of science in an independent world of ontological depth, knowledge can be seen as contingent and conceptually mediated. Frameworks, theories and concepts should be viewed as provisional, reflecting the relative nature of knowledge in search of truth (Bhaskar et al., 1998). CR relies on a combination of epistemological relativism and judgemental rationalism, whereby:

> *The combination of epistemological relativism and judgemental rationalism allows us to assert that, although our knowledge is fallible and without sure foundations and is always knowledge under particular*

[33] The 'critical' of critical realism concerns (1) critique of the flattening of reality implied by empirical realism, (2) critique of the tendency to limit explanation to either the individual or the collective, (3) critique of the universalizing claims from positivism (4) a view that the causes of social phenomena can be situated within social systems, and (5) an opportunity for critical reflection (Danermark et al., 2005)

> *socially and linguistically mediated descriptions, nevertheless there can be rational grounds for preferring one to another competing description (belief or theory).*
>
> *Bhaskar, 2016, p. 25*

Thus, judgemental rationality secures the possibility to make informed choices about theory and in the pursuit of knowledge that is both practical and serious (Bhaskar, 2016). It asserts that "*notwithstanding the daunting complexity of the world and the fallible and situated character of knowledge, it is possible to develop reliable knowledge and for there to be progress in understanding*" (Sayer, 2000, p. 31).

Underlabouring this thesis with CR

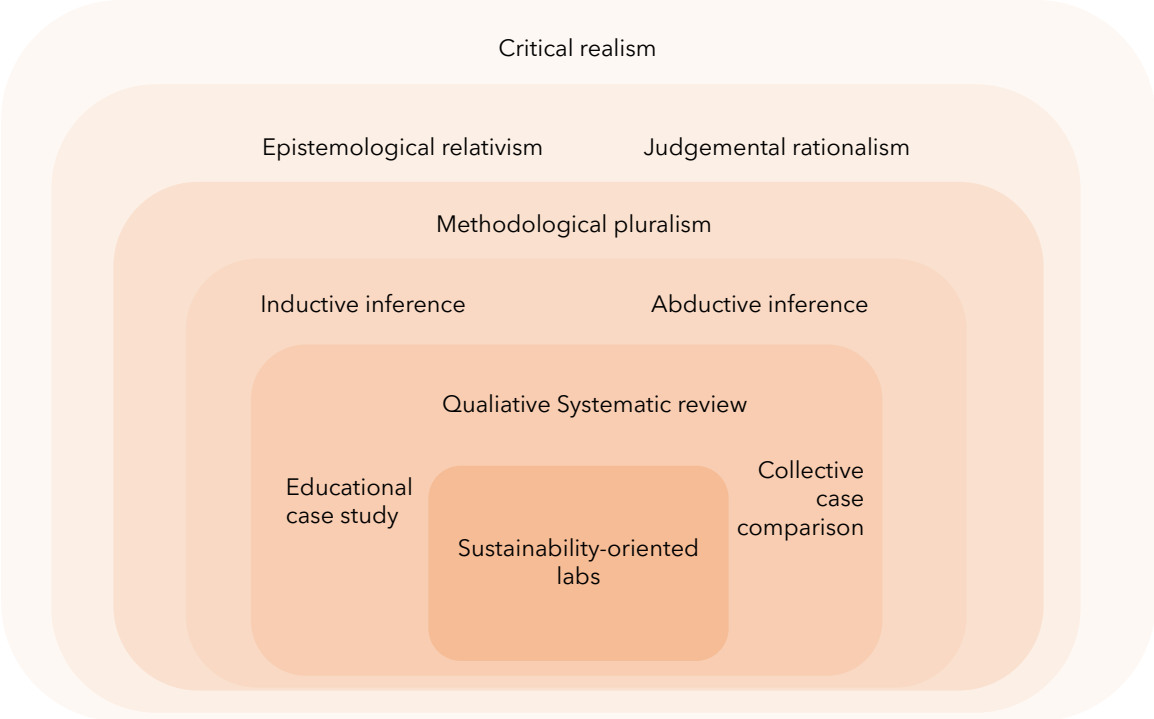

Figure 3: Research strategy underlaboring this thesis

Knowing that philosophy of science in not something that "just is", but rather an ongoing process of development over time, a critical realist approach has taken form in this thesis in various ways**.**

First, CR is best understood as a maximally inclusive philosophy of science (Bhaskar, 2016). This means that there is room to develop epistemological and methodological positions within an ontologically realist position. I recognize the importance of the socially constructed nature of meaning, without limiting forms of analysis and understanding to this. Such a view is in contrast to more radical social constructionism, where reality operates

purely as a social construction (Alvesson & Sköldberg, 2017). Epistemological considerations have been seen as a point of underdevelopment within CR, given that it establishes the primacy of ontology over epistemology. Despite this, my view is that it caters to a range of mild to moderate constructivist positions whilst at the same time viewing these as constructions of 'something' (Mingers, 2014). This difference is exemplified by Midgely (2003): "*when we look at the Himalayas, every one of us sees them differently. But none of us can think them away, nor put them there in the first place*" (p. 41).

Second, CR appeals to me as a way of doing and thinking about praxis. It seeks enhanced reflexivity and transformed practice (Bhaskar, 2016). Given the importance of transformation through engagement, this thesis is inspired by an applied version of CR. Thus, CR recognizes the highly creative aspects of the practices of doing science, comprised of both application and discovery. Methodologically, pluralism is not only possible, but it is activitely encouraged in applied versions of CR. In terms of my research strategy, rather than applying theories in a deductive manner, its work concerns praxis as a form of theory-informed practical action (Ison, 2010).

A praxis approach is compatible with CR underlaboring, carrying an extended weight on reflexivity within systems as well as the need to juggle various roles and perspectives (Ison, 2010). My research strategy, particularly in research phases two and three, acknowledge that the movements between knowledge and action are plural and multi-directional. Knowledge can unfold in the process of doing, which can in turn lead to further doing and learning (Caniglia et al., 2021). In addition, transformative research asserts that it will invariably be wrapped up in the capacity to act (Hölscher et al., 2021). Therefore, application and discovery may form through recursive interplay. As highlighted by Cockburn (2022), CR *"is oriented explicitly towards methodological pluralism, and to an agenda of transformative societal change, enabling transdisciplinary researchers to play the multiple roles expected of them"* (p. 363). In the context of educational research and learning-orientations, scholars have noted how it offers a pathway to nurture educational practices that are both explanatory and transformative (Khazem, 2018). With this view, comes the potential of such practices to either reinforce, or transform, existing structures (Bhaskar, 2016; Mingers, 2014).

Third, CR as both meta-theory and applied praxis, is highly systemic. In critical realism, systems can be understood as consisting of elements that are related to eachother. The patterns and nature of these relations constitute the structure of the system. Not only are they discrete, but systems exist *within* larger systems and *as* larger systems. For example, children exist as a series of biological and neuro-skeletal systems. They are discretely bound as a system, as a being. At the same time, children are situated in educational systems, social systems, natural systems, to name but a few. Depending on whether we zoom in or out,

constituting patterns of relation come into view. In order words, due to the hierarchical or nested nature of society, we simultaneously constitute, *and are constituted by*, systems.

Yet, a child is irreducible to its biology, and educational systems are irreducible to only children. Within systems thinking, and from a CR perspective, this crucial detail is captured by the notion of emergence. The entity of a "child" results from, but is not possessed by, any of its parts. The anti-reductionist notion of emergence is central in strands of systems thinking influenced by complexity thinking, cybernetics and soft systems thinking (Mingers, 2014; Cilliers & Prieser, 2010). Moreover, emergent powers are both fixed and fluid. The beauty of irreducibility is that it captures not only systems as is, but also the unfolding of levels and systems over time[34]. Children unfold into adults; flowers emerge from buds. Ontologically stratified systems, then, contain emergent properties that make them more than the sum of their parts both now and into the future. This point is summarized by Mingers (2014):

> *At each level, systems, with their emergent properties, interact with each other in a manner governed by their structure of relationships, generating a new level of system with its own emergent properties*
>
> *p.87.*

Fourth, by leaning on an applied approach to critical realism, this work actively recognizes both the open-ended nature of systems as well as the intentionality of normative research. Holding an open, yet embedded, orientation is therefore an important entrance for my research strategy. It has affected my view of labs as "in-between" spaces, as well as my conceptual interests in boundary work. To turn to the example of the child, some boundaries may be easier to discern than others. From a CR perspective, however, one might assert that they are observer-dependent constructions. That is, boundaries do not necessarily "exist" in open systems. Through the process of bounding, however, we reconstitute a system as having internal relations, an external environment, and a level of lamination (Avelino & Grin, 2017; Midgley, 2000; Mingers, 2014). In the words of Cilliers & Prieser (2010), it enables the system "to be". At the same time, CR asserts that boundaries are not *purely* construction. They can be physical, non-physical, actual or conceptual. Regardless, they are constructions of "something" that mediate the independent nature of reality (ontology), and our knowledge of that reality (epistemology). Given that observation

[34] Mingers (2014) notes that emergent properties can be resultant, compositional, interactional, synchronic or diachronic.

is also an act of intervention, and that observers exist as systems within systems, boundaries are also constructed by *someone.*

In summary, this thesis is concerned with contributing with not only *descriptive* and *explanatory* knowledge regarding sustainability-oriented labs in real-world contexts. It holds an ambition to *actively participate* in both the *design* and *development* of labs, particularly in the context of education as learning spaces, and the *transformation* of *praxis within labs*, through theory-informed reflection and action. A critical realist underlabouring fulfils these concerns by setting the basis for (a) an ontologically realist, yet epistemically inclusive approach as labs, as well as phenomena in labs, (b) a meta-theory that promotes methodological and positional pluralism, (c) an overtly systemic orientation that recognizes the *relational*, *nested*, and *emergent* nature of a stratified ontology, as well as (d) an applied yet reflexive attitude, one of *praxis*, towards research that approaches challenges that might elude discipline, as well as those that are oriented toward actionable forms of knowledge. As introduced in chapter 1.3, this form of praxis accompanies all research phases. Given the different methodologies within this thesis, its influence may be most visible in research phase two (Chapter 8).

6.2 Broad threads of research strategy

This thesis in underpinned by a qualitative-dominant research strategy across three overlapping research phases (Outlined in Table 3): (1) systematic review of sustainability-oriented labs in real-world contexts, (2) qualitative case-based inquiry into C-Lab, a TD educational space, and (3) a multi-case comparison of evaluation practices in various labs and transition experiments.

Qualitative research is concerned with understanding human experience and meaning in social life. Drawing upon Eisner (1979) qualitative research strategies can be described as: field-focused, organized around the self as a research instrument, interpretive in nature, concerned with attention to the particular and positional empathy. It differs from quantitative strategies in terms of research design, relation to data, movement between data and theory, as well as forms of analysis. For example, qualitative strategies typically employ a flexible research design, an attempt to connect experience with context, a non-numerical analysis of data as well as a non-positivist approach to data (Yin, 2011). This process is reciprocal and iterative, where the researcher oscillates between ideas, theory, design, data collection, analysis and dissemination. This process begins with a rough idea – an initial spark for curiosity and inspiration. The differences highlighted above may seem

procedural, but they imply a host of fundamentally different ontological, epistemological and axiological positions (Ross & Mitchell, 2018).

	Phase one	Phase one	Phase two	Phase three
Strategy \ Paper	Paper I	Paper II	Paper III	Paper IV
Purpose	Exploratory	Classificatory	Exploratory & developmental	Conceptual/ Comparative
Approach	Systematic review methodology	Empirical typology development	Educational case-study	Case-comparison
Case-based	Multi-case meta	Multi-case meta	Single case	Collective case
Research objects	Labs with an explicit orientation towards sustainability	Orientations of labs towards sustainability	Student-teacher experience in framing	Practices of evaluation
Empirical material	Peer-reviewed articles and book chapters	Sample of labs from review	Qualitative-multi-source	Multiple sources from each respective case

Table 3: Research strategy underpinning papers I-IV

Rather than represented as polar extremes, the choice of qualitative or quantitative research is practically determined by the purpose of research, object of study and research questions (Sayer, 1992). This hybrid space includes mixed methods research, where methods are flexibly combined in a more pluralistic manner (Johnson et al., 2007). Along the way, personal motivations or assumptions around science can shape the direction of a research question, or they may emerge from research curiosities or objects of study (Sayer, 1992). Strategies that draw from transitions and transformations, as well as those underlaboured by CR, are regularly described as internal to its own subject matter (Bhaskar, 2016; Hölscher et al., 2018). Researchers exist within naturalistic settings in plural ways, rather than as disconnected and objective observers. Research questions, then, evolve through praxis, whereby these questions and their significance are established via societally relevant issues.

Broadly, in this thesis my initial spark was an early empirical and analytical interest in better unpacking the phenomenon of labs in a way that pays attention to those that connect to sustainability. The initial sparks for each research phase emerged through their own research framing processes. In each chapter in part three (Chapter 7.1, 8.1 and 9.1) I describe what might be understood as 'step 0' for each phase.

6.2.1 Case-based research

> *A case may be simple or complex. It may be a child, or a classroom of children, or an incident such as a mobilization of professionals to study a childhood condition. It is one among others.*
>
> *Stake, 1998, p.134.*

Case research concerns the complexity of the social world. It is an umbrella term for a rich set of epistemologies, methodologies and research fields. Broadly, case-based research is particularistic, descriptive, heuristic and inductive (Merriam, 1988), generating thick descriptions of a complex social setting. Adelman (1980) argues that case research brings research closer to action, given its embedded nature. Case researchers achieve this by way of "why" and "how" questions, searching for theoretical or empirical entry points in phenomena (Yin, 2011). Case studies cater to research designs that are both intensive and extensive; the former concerns in-depth investigations of smaller cases, often qualitatively, with an interest in moving towards mechanisms, whereas the interest from the latter lies in seeking demi-regularities across larger samples (Danermark et al., 2005). Depending on the units of analysis, cases can be bound at sub-individual or individual up to the national level.

There are numerous points of entry and exit when demarcating social life. As a result, cases do not simply "exist". They do not arrive to us neatly packaged, regardless of how it may often seem. Rather, social actors and their activities are nested within multiple systems at the same time, interacting and feeding back onto each other. Systemically then, I exist in multiple ways within the cases that concern my thesis, and to think otherwise would counter the role of ethics within my work. The entangled nature of society as "systems within systems" is exemplified by Meadows (2008):

> *A school is a system. So is a city, and a factory, and a corporation, and a national economy. An animal is a system. A tree is a system, and a forest is a larger system that encompasses subsystems of trees and animals. The earth is a system. So is the solar system; so is a galaxy…Sand scattered on a road by happenstance is not, itself, a system.*
>
> *p. 11*

The in-betweenness of labs highlights the presence of competing empirical boundaries for investigation. When understood through an open-ended systems perspective, the goal of case research is to bound a particular chunk of the world as a case of *something* (Lund, 2014). Cases can therefore be understood as softly bounded systems, where closure brings an underdetermined reality temporarily into view. As such, the researcher is called upon to

consciously make boundary judgements to make a slice of reality "study-able". A boundary must therefore be drawn so that one can identify and distinguish systems from one-another, whilst at the same time recognizing the interconnectedness. This view is echoed by Cillers & Preiser (2010), who state that:

> *the boundary is thus constitutive of the system; it enables the system to be. It does not simply close the system off, it facilitates interactions between the system and its environment"*
>
> *p. 9*

Research phase one can be understood as a case of "cases". We adopted an inductive case survey method to facilitate the structured organization of multiple qualitative cases, as well as to derive insights that are exploratory in nature and extend beyond those of a single-case approach (Newig and Fritsch, 2009). The boundaries around the empirical realities of every lab included in the lab were in some ways taken for granted. Such an approach brings with it the advantage of resolving issues associated with bounding multiple labs. At the same time, it runs the risk of boundary-setting that misrepresents the relations between labs and their context. These considerations highlight the importance of reflexive research approaches that take seriously the steps taken when moving from single case to multiple cases as part of a review process.

In research phase two, our case approach is distinguished by a dual focus. It is both a case study of a particular learning environment, as well as case-based inquiry into the phenomenon of challenge framing within this environment. There was a growing interest to investigate challenge framing in C-Lab, accompanied by a need to engage with challenge framing as connected to the course. Here, the boundaries of the case concretized through a continuous interplay between a fuzzy research object, provisional research questions and an emerging methodological approach (Sayer, 2002). An educational lab such as C-Lab can at the same time be bound at the person, the workshop, the classroom, the course, the university, the district, the city, and so on and so forth. Despite its challenges, the advantage of this type of case– educational practice and research – is that *"it can 'close in' on real-life situations and test views directly in relation to phenomena as they unfold in practice"* (Flyvbjerg, 2006, p. 235).

In research phase three, we adopted a collective-case study approach, organized around experimental practices for evaluation. Collective case studies are a multi-case approach of sorts, where there is an interest in learning more about a particular phenomenon (Stake, 1995). The intention of this phase was to therefore bring three experimental practices closer to one another, knowing that their variation may compensate

for their disparate nature, thus possibly allowing us to learn more about experimental forms of labs and experiments. An advantage and risk of collective cases is that "*individual cases in the collection may or may not be known in advance to manifest some common characteristic*" (Stake, 1995, p.138).

6.2.2 Empirical material

Research phase one focused on the identification of labs with an explicit orientation towards sustainability. Its empirical approach was the most extended. This can be seen as an overarching strategy for both papers I and III, where the sample of labs collected in paper I underpins the classificatory approach of paper III. Navigating review material can quickly feel like moving through a labyrinth, where one wrong turn can bring you back to the start. Reviews of this kind demand an approach that organized secondary sources across various stages of the process. In the beginning of the research design, I focused on developing helpful habits for storing, reordering and navigating a large data set. Over time, decisions were made to select and refine this set. For example, a broad search string served as a net to catch relevant sources and include/exclude criteria served to identify and refine the empirical material. This search string functioned as a filter, intended to narrow a large unstructured field based on research interests and scope. Empirically, we were reliant on a combination of academic literature and book chapters on cases, supported by complementary material from articles, websites and reports. This additional material served to corroborate details within articles and chapters, and to also enrich the more practical/procedural elements of each lab (such as duration, funding, partners, model of change).

If the empirical nature of phase one was the most systematic, research phase two could be understood as the most dynamic. In phase two, I was in a setting where lack of empirics was not an issue. As an action-oriented learning environment, multiple streams of experience were intersecting, and emergent insights felt like they were bubbling up. To foreground the empirical nature of C-Lab as a case of "something", we decided to search with the idea of empirical windows. This meant that as designers, teachers and researchers, we were searching for opportune moments where it became possible to learn around a research object in C-Lab without compromising other roles or tasks.

Searching for empirical windows comes with advantages and disadvantages from a methodological point of view. It enables us to enter educational environments practically, conceptually and methodologically, without feeling like all three positions compete for time and attention. In searching for opportune moments, it can become possible to rapidly

mobilize around a research object if the timing is right. Combining these positions also creates possibility for learning loops between research and action, where emergent findings can feed back into learning environments and enrich TD praxis. At the same time, searching for empirical windows might mean "staying with the mess", and understanding that choices in the educational environment may impact research designs/outcomes.

The intensive nature of phase two encouraged an array of empirics, providing a base for theoretical and data triangulations (Yin, 2011; Stake, 1995). Within this PhD, this meant creating a basis for various forms of observation and reflexive knowledge as part of praxis. I developed observational, reflective, theoretical and methodological notes as a basis for qualitative research (Richardson, 2000). Across all courses, reflection sessions were scheduled to reflect upon observations and experiences. In paper II, we oscillated between experience-based and theoretical forms of inquiry. Moreover, we focused on trying to bring multiple layers of empirics into contact with eachother. This included reflective diaries as an instrument for student learning and part of an empirical window; layers of observation that were collected over time and intensified around a particular course; design and course expectations, as well as all artefacts and outputs from the course.

If phase one was the most systematic, and phase two the most dynamic, it might be helpful to understand research phase three as the more readily structured. Its ambition was to create a methodological frame that was inspired by conversation and experience-sharing. Collaborators brought with them their own "case" of evaluation, which in turn included an array of material that was specific to each case. Rather that unpacking and unfolding all the empirics, we began with the question: *given what we have, and given what we have done, what can we learn from eachother?* The exchanging of experiences, collaborative writing, and critical questioning of initiatives through the lens of evaluation resulted in this study. Each collaborator was encouraged to revisit their empirics iteratively during the development of the research object. In this form, writing about, and reflecting upon, evaluation serves to build collective capacities to situate and relate our practices in a humble manner, and with an interest in preserving context.

6.2.3 Analytical movements

In research phase one, three analytical movements were made. *First*, we unpacked sustainability-oriented labs with support of a descriptive analytical framework. This framework was iteratively developed to support subsequent stages of analysis with a large empirical collection. It served as the first moment when the empirics of each case were disassembled and reassembled, translating raw qualitative data into more structured

patterns of meaning (Yin, 2011). This stage included various lines of inquiry, ranging from details regarding intent, distribution and process characteristics of labs (Paper I). Our *second* analytical movement involved engaging with discourse elements of labs, as well as organizing dimensions, to reach beyond previously assumed conceptual labels (Paper III). This movement enabled us to trace previously established conceptual roots, and to move beyond them.

Our *third* analytical movement involved moving towards an empirically grounded categorization of labs according to their engagement with sustainability. We iteratively engaged with a typologization process that had been previously developed by Kluge (2000). This consisted of re-analyzing empirical categories from earlier stages of phase one, with the intention of more focused insights on sustainability. Its intent was comparative and synthetic, meaning that the eventual goal was a series of types that were internally consistent to a degree, but distinctive from each other. This step therefore involved a re-organization of categories from stage one, as well as a reanalysis of the underpinning data by way of thematic coding. Empirically grounded typologies mediate between empirics and theory, meaning that the chains developed for each type arose out of the empirical data, but became no longer reducible to this data.

Phases two and three necessitate research of a different nature than in the first half of this PhD but remain tightly linked with my philosophy of science and thesis aim. They can generally be characterized by a movement towards theoretical and empirical engagement associated with labs with an interest in perspectives on learning. In research phase two, we adopted an abductive-prominent logic; given that realities are under-determined, and that our understandings are both provisional and contingent, we were searching for the best available understanding of the experiences of challenge framing environments. We approached reflective diaries in a more inductive manner – their design alternated between structured and semi-structured reflection prompts for students across the duration of the course. These prompts were however the product of praxis in C-Lab in the preceding two years. They formed the basis for thematically analysing layers of experience within the C-Lab course.

In research phase three, we engaged in a form of comparative analysis of evaluation practices. We co-produced a reflective frame for discussing and writing about immanent experiences from within each case of evaluation. This frame was organized around three guiding parts: (1) Exploration of a specific challenge with the evaluation of transition initiatives, (2) A descriptive account of each transition initiative in relation to a given challenge, and conceptual grounding, and (3) Case-specific reflection, based on experience harvesting and reflective conversations.

Part Three: Research phases

In part three, I dedicate one chapter each to the research motivations, methodological approach and findings from each research phase **(Chapters 7, 8 and 9).** I do this to provide sufficient space to trace connections between the overarching motivation and background of this thesis, and the contributions that are relevant for each research phase:

7 Phase one: Sustainability-oriented labs in real-world contexts

7.1 Arriving at research phase one

Research phase one marked the starting point for my doctoral journey. I had practically experienced that labs in the real world can vary wildly in terms of their orientation and framing language. My masters research centred on urban living labs as an organizing frame, whereas I had multiple years' experience in living lab research and practice. I perceived that in many cases sustainability felt far from the larger conversations around lab development. At the same time, I found the variety of labs fascinating, given that I was participating in a growing agenda around the democratizing of knowledge, place-making and experimentation. Given the growth of labs, and their movement within and across different fields of research and practice, I was interested in better unpacking this variation with a more directed focus on sustainability challenges.

Research phase one coincided with my involvement in an agenda setting process as part of our larger research group. Collectively, this curiosity was broadly shared by my colleagues within the research team, researchers who had also been engaging with labs praxis from different angles. Given that we had shared interests yet brought with us various conceptions of lab theory and practice, we made the decision that an exploratory approach would allow us to best enter this space with open expectations around what we would arrive at. Despite this openness, there was a broadly held feeling that by better understanding the normative nature of labs, in a way that might transcend concept, new possibilities for practice might arise.

The aim of research phase one was *to unpack labs in real-world contexts according to their orientation towards sustainability*. It was guided by two primary research questions:

RQ1: How might sustainability-oriented labs in real-world contexts be understood? (Paper I)

RQ3: In which ways do sustainability-oriented labs engage with sustainability and how can they be categorized? (Paper III)

Practically, this research phase had uncertainties regarding the time horizon for this approach and the expansive nature of its data collection. In addition, there was an expectation that this design might yield insights that were unanticipated, uncomfortable, or even contradictory. It marked a methodological attempt to gain oversight within a broad field through a boundary object. What became clear along the way was that a research design of this kind requires highly reflexive structures, providing an opportunity to work through and compare our own assumptions as part of various epistemic communities.

7.2 Methodological approach for phase one

Phase one consisted of a methodological strategy that ran from 2018 - 2022. We chose a qualitative systematic review process as part of a two-pronged ambition. First, we sought to identify labs that hold an orientation towards sustainability in the real world. Second, we then aimed to explore and investigate the characteristics and defining elements of these labs.

Systematic reviews belong to a broad family of methods and research designs that are focused on collecting and/or integrating secondary sources of data. The "systematic" nature of these reviews lies with their protocol-driven and stepwise collection of data (Egger et al., 2001; Thomas & Harden, 2008). Systematic data collection is chosen over narrative reviews or smaller case-samples as, despite their advantages in the creative and interpretive processes of meaning making, they are not best suited to larger reviews. Through the lens of positivism, systematic reviews have become emblematic of a "golden" standard of research, with the view that aggregated evidence provides a more robust and conclusive body of knowledge (Sayer, 2002; Sovacool et al. 2018). More recently however, systematic reviews now include qualitative and mixed approaches to synthesis (Bryman, 2012; Grant & Booth, 2009).

Qualitative systematic reviews, whilst relatively new in comparison to quantitative counterparts, are organized according to the research object and function of the review (Macura et al., 2019; Thomas & Harden, 2008). They attempt to incorporate into the review plural forms of evidence and bodies of knowledge that might previously be labelled as subjective and of low-quality (Dixon-Woods et al., 2006). Within doctoral research, they are encouraged as a boundary-spanning activity that provide a means for generating oversight of numerous fields of research or phenomena:

> *Undertaking a qualitative systematic review provides a vital means to know and tune into the past conversation in your topic area that allows*

the researcher to position themselves and their work substantively, ontologically, theoretically, and methodologically in this landscape.

Clark, 2016, p. 1

The qualitative systematic review is thus profound in its epistemological implications for understanding evidence in decision-making processes. At the level of *scoping*, it rejects a rationalist prioritization of papers for analysis, in favour of plural and inclusive quality decisions (Dixon-Woods et al., 2006). This makes it possible to include evidence that is narrative-descriptive, theory-oriented and empirical (Thomas & Harden, 2008). At the level of *process*, it accords status to the unique and creative roles at play in reviews as interpretive acts. This reflexive layer enhances the capacity of reviewers to better attune to, deliberate upon, and adapt to, realizations throughout the process (Dixon-Woods et al., 2006). At the level of *analysis*, qualitative systematic reviews de-centre statistical and bibliometric analyses, favouring organic, creative and interpretive approaches to synthesis (Greenhalgh et al., 2005). This broadens the range of analytical techniques that are available for reaching new levels of meaning in review processes, enabling new choices to be made by reviewers.

This research phase was concerned with laboratories in real-world contexts as the guiding object of study, and sustainability as a multifaceted factor of importance. Due to their ID-TD nature, knowledge of these labs is scattered across different disciplines and contexts. In research phase one, we therefore chose to broadly consider various lab approaches, underpinned by sustainability as an anchoring concept to systematically guide the collection of cases. This is reflected in the choice of (1) a broad search string that maximized inclusion, (2) gradual narrowing with exclusion criteria and (3) an inclusive approach to field of research (See Figure 4).

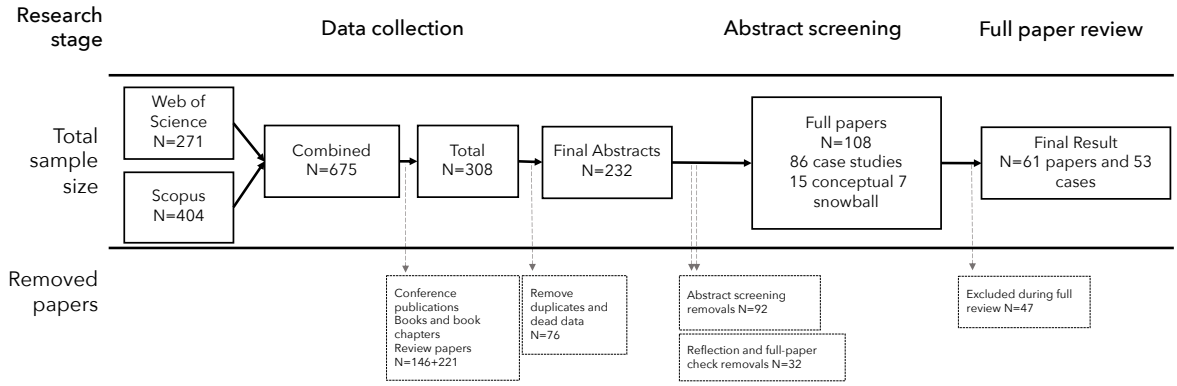

Figure 4: Systematic literature review process for Paper I. Source: McCrory et al. (2020)

Following a collection of labs, we then adopted a qualitative case-based approach to classify labs according to their properties. Methodologically, we engaged with a four-step typology process proposed by Kluge (2000), including the development of dimensions, grouping of

cases, analysis of empirical regularities and subsequent construction of types and typology (see Figure 5).

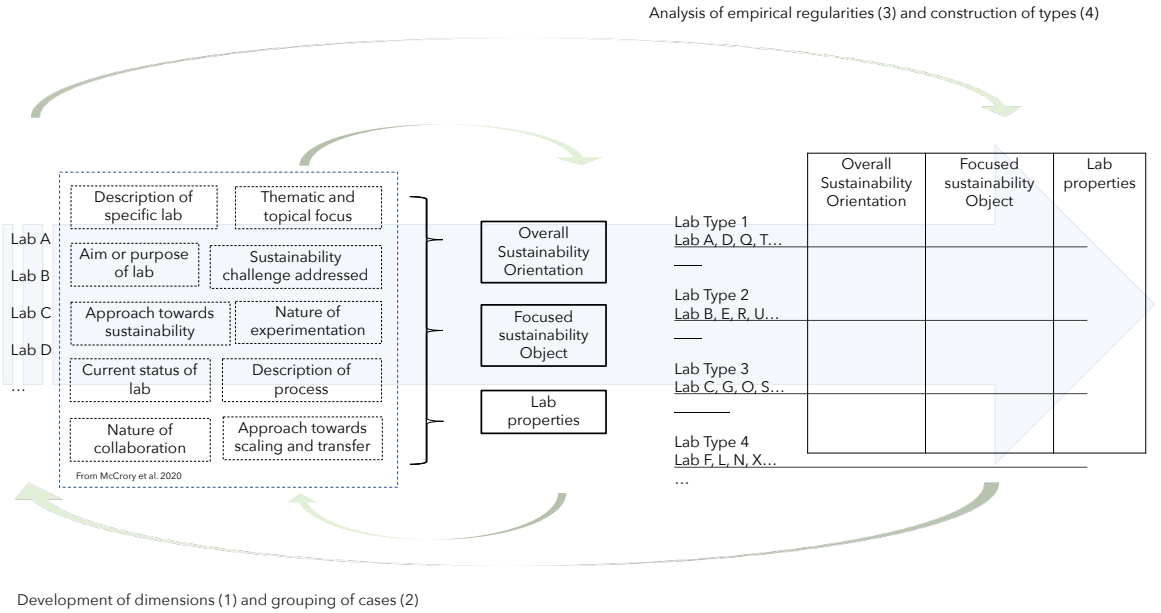

Figure 5: Schematic of typology process adopted in Paper III. Source: McCrory et al. (2022).

The process of typology development entails a broad reflexive approach where one assesses, classifies and examines an array of material (Berg & Lune, 2017). We developed a provisional set of dimensions to support in classification: (1) overall sustainability orientations, (2) focused sustainability objects and (3) a provisional set of properties of sustainability in labs.

7.3 Unpacking sustainability-oriented labs

In paper I, we identified and began to unpack 53 sustainability-oriented labs in real-world contexts. Through a mixed-methods analysis, we presented three levels of results aimed at (1) exploring the distribution and diversity of these labs, (2) discerning the research communities from which labs are conceptualized, and (3) understanding the characteristics of lab practices (Figure 6). First, we provided an overview of the diversity in distribution, thematic focus, and setup of labs. Although sustainability-oriented labs in real-world contexts were found across 22 different countries, they are predominantly a European phenomenon of experimental activities. Thematically, labs ranged from the built environment, towards food, education, and participation. Despite diversity in scale and physical setting, a common collection of labs was physically situated in, and oriented towards the local level. A collection of labs was connected to universities at the campus level; others were bound at the district level within cities.

Second, paper I found seven different research communities where sustainability-oriented labs have been conceptualized. These include:

Living labs (LL): An inclusive learning environment for real-world testing of telecommunications that evolved alongside participatory user design paradigms. Common conceptions of co-creation have been developed within this tradition.

Urban Living labs (ULL): A recent contribution on labs that combines co-creation from LL with urban experimentation and governance literature. ULL have been developed as an extension of the previous roots from living labs literature, emphasizing the importance of social learning and experimentation in bound contexts.

Urban Transition labs/Transition Management (UTL/TM): A reflexive governance approach that incorporates theories from sociology, complexity theory and governance theory. UTL stand as a particular approach to transition management in urban contexts. It brings with it a futures orientation, as well as an interest in co-creation and governance.

Real-world labs (RWL): A predominantly German conceptualization, with explicit roots from TD and sustainability science. RWL bring a strong science-as-orchestrator stance, as well as a systematic interventionist logic with an interest in scaling, transferring and generalizing lab outcomes.

Evolutionary Learning labs (ELL): An explicit learning approach that has been inspired by systems thinking and learning sciences. ELL proceed through a cyclical methodology to move from learning about systems, towards policy intervention.

Change Laboratory: A formative intervention methodology rooted in cultural-historical activity theory. Change Laboratories are learning interventions focused on the transformation of activity systems. It combines theorizing with intensive, longitudinal empirical research.

Transformation labs (T-Lab): A conceptualization rooted in SE systems, with practical and conceptual interests in the development of transformative spaces. Emphasis is placed on values recognition and collective agency around complex and contested challenges.

Third, paper I presented a triadic view of labs of labs as *spaces, processes, and ways of organising* around sustainability challenges. *Labs as spaces* highlights their situated nature, as experimental sites, arenas or settings. *Labs as processes* highlights their process-based character and interest in co-creation. These processes are diverse in their problem-solution-challenge orientations, engagement with temporality, systems focus as well as view of participation. *Labs as* ways of *organising* highlights the relational dimension of their work. This included models for funding, assumptions on the role of stakeholders, as well as their

disposition to change as a mode of governance. Labs develop through these three dimensions mutually, whereby sustainability is a dynamic emergent property.

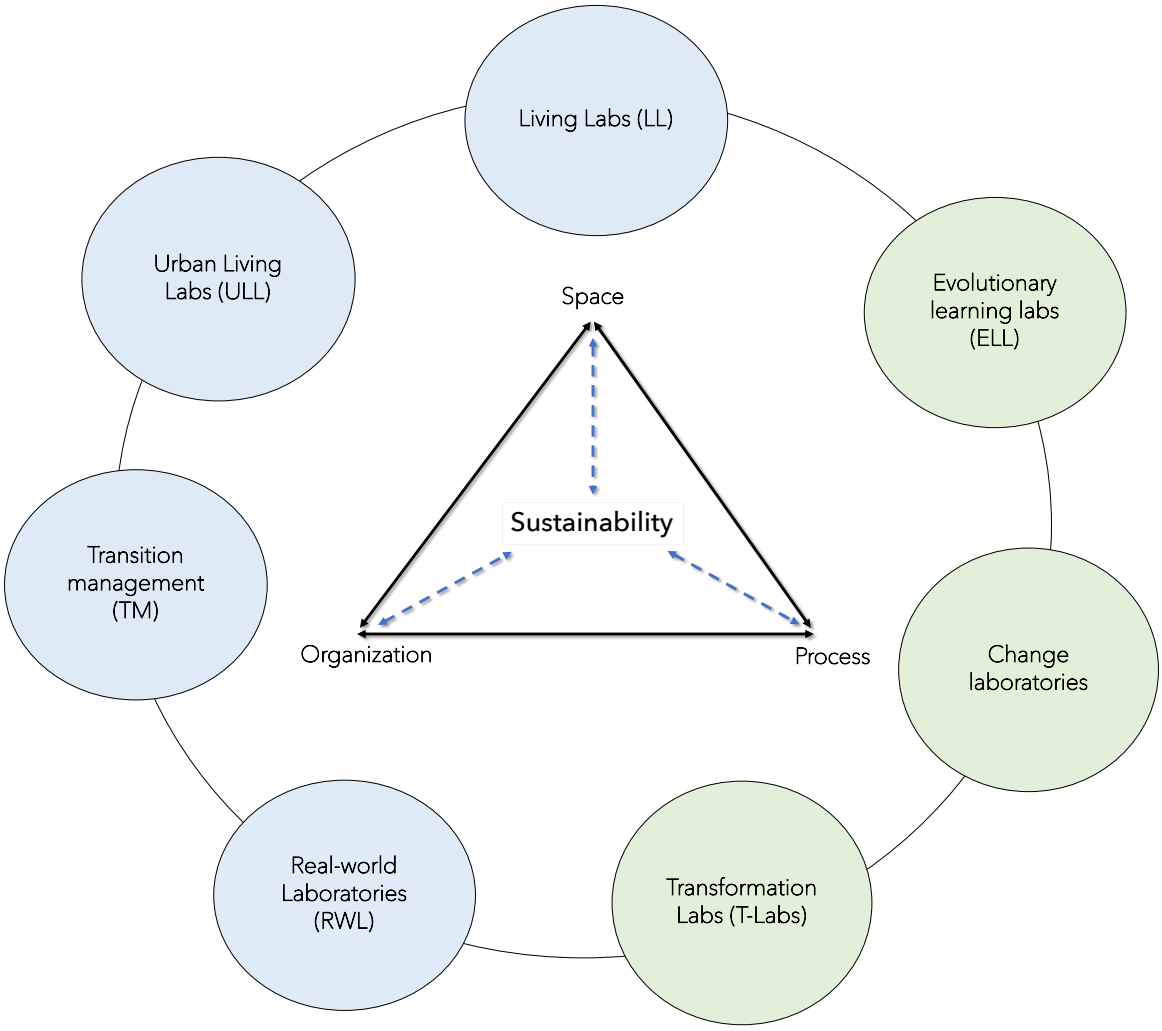

Figure 6: Presentation of lab discourses and practices from Paper I. Source McCrory et al. (2020)

Paper III built upon and extended the insights of paper I by categorizing sustainability-oriented labs in real-world contexts according to understandings of, and approaches to, sustainability. It was motivated by the claim, articulated in paper III, that the notion of sustainability remains oversimplified, obscuring how labs differ in their normative orientations. This claim is established within the transitions community as part of a broader mission to take sustainability seriously in place-based experimentation. One reason for this is the recognition that sustainability is tightly linked to the direction and orientation of transition processes (Köhler et al., 2019; Stirling, 2009). Additionally, the motivation for this paper emerged from paper III, where *"for some, sustainability was treated as an exogenous environmental challenge to be solved through technological systems. For others, it was treated as a contingent manifestation of a complex, multi-dimensional phenomenon"* (McCrory et al., 2020, p. 12).

The central output of analysis takes the form of a typology (paper III), a device for classification with the aim to *"create an arrangement from data reduction that helps us understand complex events, processes, or constructs"* (Suter, 2012, p. 21). Through our analysis, we arrived at six different types of sustainability-oriented labs: (*1) Fix and control, (2) (Re-)Design and optimize, (3) Make and relate, (4) Educate and engage, (5) Empower and govern and (6) Explore and shape.* The types are briefly presented in Table 4 according to their overall and focused sustainability descriptions, and further expanded upon in Table 5. They broadly differentiate overall sustainability orientations as matters of technology, consumption, participation, education, the urban or complex challenges respectively. In addition, they situate sustainability as issues of efficiency, lifestyles, practices, university-society relations, governance, and undefined local contexts.

Lab type	Overall sustainability orientation	Focused sustainability object
Fix and control	Technological innovation/change	Eco-efficient technical systems
(Re-)Design and optimize	Consumption and user involvement in production	Sustainable lifestyles and behaviours
Make and relate	Participation and cultural development	Practices and relations in local communities
Educate and engage	Education for sustainable development (ESD)	University-society relations, students as change agents
Empower and govern	Interconnected and multi-facetted (urban) challenges	Regeneration and governance
Explore and shape	Complex, contested, and as a challenge to linear approaches	Systemic and collective interventions in local context

Table 4: Summarized typology of sustainability-oriented labs. Source: McCrory et al. (2022)

The development of six distinctive types – ranging from *Fix and control* to *Explore and shape* – illustrates a spectrum of these labs according to generic and situated sustainability, as well as core properties. Within each type lies a set of collectively shared yet individually distinctive properties, serving as a basis for comparison within (horizontally) and across (vertically) types. This typology offers explanatory power in inviting a discussion around the diversity that exists across different labs in sustainability transitions and transformations, relevant for living processes of classification, informed lab design, and reflexive lab praxis.

Properties / Lab type	Constructed as	Ambitions	Foregrounding	Collaboration	Experimentation	Approach to innovation	Nature of process	Illustrative lab case
Fix and control	Research/private testbeds at city/district level	Technical roll-out	Technology in responding to sustainability	Instrumental, citizens as receivers	Controlled, technology-centred experiments	Market-oriented innovation, technology as an end	Implementation and evaluation	*T-City Friedrichshafen (Lee et al., 2011; Menny et al., 2018)*
	Closed, research-driven experiments on uni campus	Technical scaling across buildings	Technology in responding to sustainability	Expert-driven	Controlled, technology-centred Experiments	Market-oriented innovation, technology as an end	Implementation and evaluation	*University Cape Town (McGibbon et al., 2014)*
(Re-)Design and optimize	1) Real-time controlled, or 2) real-world uncontrolled environment	Changing user-consumption and speed to market	Technology as an enabler	User-focused with hybrid research involvement	User-centred experimenting, prototyping and evaluation	User-driven, with tech challenge at starting point	Design-thinking and ideation techniques	*SustLabNRW (Baedeker et al., 2017)*
Make and relate	Hubs, constructed and bound at the local level	Space in local setting	Communities, practices and relations	Voluntary and driven by locals	Material and social learning-by-doing	Social innovation	Informal and self-organizing	*Trial and Error (Hector, 2018)*
Educate and engage	Educational learning environment	Multi-stakeholder real-world education using TD tools	New ways of educating	Student-stakeholder-society; researchers as teachers	Curriculum and learning	Curriculum innovation	Formal and sequenced, bounded to curriculum	*University of Wisconsin Lab (Lindstrom et al., 2015)*
Empower and govern	Urban, partnership-based and inclusive	New ways of governing and organizing around community challenges	Partnerships and governance	Driven by communities/ researchers	Relational and institutional	Technology as means; innovation as participatory	Varying formality	*Mooi Mooier Middelland (Puerari et al., 2018)*
Explore and shape	A shared exploration	Grasping complexity	Methods and process	A pre-condition, with researchers as process designers	Systemic, value and challenge-driven	Systemic - opening boundaries within which innovation may occur	Formal, rigorous, and sequenced	*Xochimilco T-Lab (Charli-Joseph et al., 2018)*

Table 5: Typology of sustainability-oriented labs – detailed. Source: McCrory et al. (2022)

8 Phase two: Learning to frame complex sustainability challenges - A Challenge-Lab case study

8.1 Arriving at research phase two

> *Educational activity, whether teaching, evaluating, or curriculum planning, is much like the artistic activity a painter engages in as he or she copes with emerging visual configurations on a canvas. Each stroke alters the pattern, each new colour changes the whole. This dynamic seeks ultimately a happy resolution: the realization of artistic virtue through the creation of an organic entity that "works." As the artist articulates new problems, new decisions must be made; when old decisions become routine (a part of the artist's stock response), new questions must be formulated so that new solutions can be sought. The joy of the ride, even more than the arrival, is the motive force behind the artist's work.*
>
> *Eisner, 1979, p.XII*

Running alongside my curiosity in sustainability-oriented labs, I found myself drawn to questions of education in times of transformation. This interest began as a practical interest at first. I was concerned with how to best support students in their learning journeys in the classroom. Through sustained engagement over time, my curiousity in these environments evolved beyond purely practice. What slowly came into view was how learning environments can be nurtured; how these environments are positioned and framed; and the potential of different ways of thinking about teaching, pedagogy, and evaluation.

In addition, the first research phase of my thesis (Chapter 7) revealed a growing complementarity between labs, and questions of education, where a group of labs emerged from within higher education. They "*frequently counter conventional approaches to education for sustainable development (ESD) that are teacher-centred, lecture-based and*

disconnected from real-world application. Educate and engage labs experiment with new forms of collaboration, material constellations, learning environments and curriculum designs" (McCrory et al., 2022, p.105). Their ambitions mirrored recent developments in ESD, where addressing sustainability challenges in society with and through transformative modes of education are encouraged (Wals, 2015; Lotz-Sisitka et al; 2015). Such modes demand transgressive and experimental logics, where students are supported in both unravelling the complexities of sustainability, and developing agency in taking action (UNESCO, 2014; Duraiappah et al., 2021).

Throughout my doctoral journey, I and others began thinking together both practically and conceptually about the particularities of learning that may unfold within a C-Lab curriculum. As we began, we noticed an absence of research on how curriculum designs might support challenge framing, and how students experience and learn framing processes. This is partly due to prevailing tendencies in sustainability-oriented education, where, students are invited to solve pre-established issues, but not frame them (Tilbury,2016; Pohl et al., 2020). As highlighted previously in Chapter 6 I approach my research in an emplaced manner, having been emotionally engaged in multiple aspects of C-Lab for the duration of my doctoral journey. Each year I support in the development of existing courses. I co-develop new courses and co-produce ongoing reflections and ideas. We exchange with colleagues and international peers in local, national and international settings.

In total since 2018, I have been actively involved in ten variations of C-Lab that are connected to the educational missions of the university. Whilst I anchor this study more around a particular curriculum in 2020, it is important to acknowledge that its boundary (temporal, institutional, experiential) is therefore porous. This can be considered a provisional, yet necessary choice, where I empirically gravitate towards one course more than others, in one particular year, to empirically slice and bound the phenomenon of C-Lab as a study-able case.

As highlighted above, the motivation for research phase two stemmed from multiple interests in education during, in and for transformation. Real-world approaches show promise as they encourage zones of transaction between various forms of knowledge and action. This is often achieved through the thoughtful combination of research, practice, and education as a central element of curriculum development and teaching philosophy. In addition, as a group we wanted to better understand the role of the sustainability challenges as a gravitating element in these spaces. We held an interest in exploring how framing-oriented curricula work in practice and come into meaning for those involved. This is connected to a broader curiosity regarding how higher education institutions might provide conditions conducive to open-ended curriculum with transformative sustainability

ambitions. By beginning with a framing of challenges to be approached, these courses depart from apprenticeship models and problem-based learning towards learning environments that are shrouded in messiness and uncertainty. I was fascinated with how this difference can be understood conceptually, and how curriculum designers, teachers and students grapple with such challenges as curriculum unfolds.

The aim of research phase two was *to design and learn from experimental processes in higher education that are rooted in the real world.* The research presented here is an attempt to approach RQ2 of this thesis:

RQ2: As an educational lab, how does Challenge Lab (C-Lab) organize around sustainability challenges, and how do such challenges unfold?

8.2 Methodological approach for phase two

Phase two involves the design of a study of a particular learning environment, as well as an inquiry into the phenomenon of challenge framing within this environment. Within research phase two, the overarching purpose was to explore a transdisciplinary *Challenge Lab* (C-Lab) approach, as a curriculum that explicitly encourages challenge framing. There was a curiosity to better understand challenge framing in C-Lab, accompanied by a need to engage with challenge framing as connected to the course. Here, the boundaries of the case concretized through a continuous interplay between a fuzzy research object, guiding research questions and an emerging methodological approach (Sayer, 2002).

Understanding this paper as an educational case study (Bassey,1999) is important. It allows the researcher to approach an empirical situation, making necessary movements between the empirical, conceptual and practical realms of a case. At the same time, the advantage of integrated educational practice and research is that *"it can 'close in' on real-life situations and test views directly in relation to phenomena as they unfold in practice"* (Flyvbjerg, 2006). My approach, inspired by action research, co-creation and praxis (Lewin, 1946, Sanders & Stappers, 2008; Freire, 1970), attempts to expand both notions of impact in education research, as well as the mobility between research and impact during processes. It then, focuses on learning *about* education *in* education, *for* learning. This stance implies a dialogue between theory and practice that is best articulated outside of a linear logic. The interconnected nature of thinking and doing in action-oriented education settings is neatly summarized by Akkerman et al. (2021):

> *In contrast to theoretical, descriptive, and explanatory research, where impact depends on afterthought and re-action, intervention research establishes impact already in the immediate relation and collaboration with participants and local settings.*
>
> *p. 422.*

Thus, from explanatory or descriptive knowledge, the flows between explaining and acting are plural. Stretched to its extreme, then, one could argue that by the time you read this chapter, the impacts of this research can already be found in how we teach, in our educational praxis, and in the courses that have come to pass. This might seem reasonable, and I do feel it is a central element in this phase. At the same time, it is only reasonable insofar as impact is conceived of as purely educational praxis. However, for me, a strength of integrated education research lies in how it produces threads of impact across multiple domains. For example, this research phase, including paper II and the world it concerns, has generated explanatory, descriptive knowledge that may (1) resonate with alternative contexts and settings and (2) provide entrance into layers of reality where generative mechanisms can be traced (Danermark, 2005), (3) establish a basis for theory-informed practical action in a setting (Ison, 2010), (4) support in moving forward in learning situations (Akkerman et al., 2021), and (5) transform questions of doing and knowing, into questions of being and becoming (Akkerman et al., 2021; Vogel & O'Brien, 2022; Freire, 1970).

Such knowledge can also be theoretical[35] or empirical, given the continuous interplays between these two realms in unfolding settings. Moreover, it may trigger forms of reflection and introspection, conditions for deep forms of learning in different spaces and at different times (Schön, 1982; Freire, 1970; Brown, 2010; Ison, 2010). Conversely, explanatory, descriptive and theoretical knowledge can also flow *from* experiences and observations in C-Lab, as well as parallel experiences that exist inside and outside of case. These may be individual, collective, abstract or concrete. Observations fuel a search for explanatory, theoretical or descriptive knowledge; knowledge-experience combinations re-direct back into settings, sustaining observation, informing action, producing resonance. Action creates meaningful movement forwards.

Within all of this is an inherently experimental quality. And as highlighted in 3.3, experimenting may not always be successful or positive. Sometimes the best theories have been those that have been most practical (Pawson & Tilley, 1997). On other occasions,

[35] As an illustration, in this research phase, various theoretical frames have matured over time, whereas others have fizzled out and become less relevant. Secondary theories and concepts have fed into the development of method, tools and processes that form an important layer of the backcasting process that is central to C-Lab.

theories have been no use at all, turned to at a time when connection and dialogue was required. The experimental qualities bring with them an acknowledgement that there are ontological limits to control (Morin, 2008; Akkerman et al., 2021). They also highlight that, although there may be mistakes, unintended feedbacks and confusion, the aspirations of such practices are towards flourishing and learning. Finally, they also signal that rather than a free for all, these research strategies strengthen reflective capacities to act in situations alongside others (Ison, 2010). The research approach in phase two can therefore be understood as an iterative, collaborative approach to research. Although paper II presents an inquiry in C-Lab, it is worth re-iterating that by reducing a course to a paper, distortions and compressions might occur. The same can be said for bounding C-Lab at a curriculum in a year. Therefore, Paper II compresses five years of engagement, and one unfolding curriculum, into a written piece. This thesis attempts to unbound it, or at least to shift the boundaries so that more might come into view for the reader.

Empirically, this research phase is organized around three layers of C-Lab. Paper II was primarily concerned with gathering diverse forms of student experience during the course. Directly related to the 2020 course curriculum, this empirical material included a series of 8-week reflection diaries for students that spanned the duration of the course. Reflective diaries provide an insight into both descriptive and reflective elements of student experience (Wallin & Adawi, 2018). In addition to ongoing process reflection, structured reflective diaries provide an opportunity to further descriptive writing by unfolding experience with layers of reflection. These reflections recruit alternative connections between course content, student experience, student history and concepts and theories. They also recirculate into course curriculum, providing insight into *learning about learning*. Ontologically, reflection diaries provide an opportunity to witness, to practice presence, to stand still, and to muddle through uncertain terrain.

In addition to reflective diaries, this course dedicated time and space to co-producing expectations as a frame for understanding progress over time. Students and teachers engaged with digital storywalling as a harvesting technique, as a way of co-producing evaluative knowledge on the course curriculum. In addition, we gathered a series of check-in and check-out notes, at the beginning and end of each week, throughout the course. Second, this study built upon design ambitions of the lab, as a combination of space, process and way of organization. Empirically, it included course syllabi, previous articles on C-Lab (Holmberg, 2014; Larsson & Holmberg, 2018; Holmén et al., 2021) and design meeting notes that began in 2018. Finally, design experiences provided an opportunity to consider observational data from course workshops and seminars, as well as ongoing reflective outputs during design and course terms.

We borrowed from curriculum theory to organize C-Lab as a layered learning space (Billett, 2006). Intended curriculum refers to what teachers want their students to learn and how, reflected in the learning objectives and the overall design of a curriculum. Enacted curriculum refers to how teaching and learning activities are designed to help students attain the learning objectives that are (actually) enacted with and by students. Experienced curriculum refers to students' learning experiences and outcomes. Hume and Coll (2010) explain the educational significance of this three-pronged analytical frame:

> *Research findings that can shed light on the match between curriculum intent and classroom reality in [. . .] dynamic and complex educational environments [. . .] are important when evaluating how effectively curriculum goals are being met and help inform decisions about what steps may be needed to improve outcomes for students*
>
> *p. 45.*

Curriculum theory argues that learning spaces can be understood as an interplay between intention, enactment and experience in their unfolding. This distinction provided a relevant and grounded frame for exploring C-Lab as a space where co-production processes may mean that student and designer experiences feed into each other to inform the development of a curriculum. Analytically, this inductive approach to data analysis takes the form of a thematic analysis, organized around the broad question *"how do students experience challenge-driven educational curriculum?"* (Saldaña, 2021). In addition, focus was placed on processes of framing that occur in such learning environments. In inductive approaches, the concreteness of empirical instances provides the basis for concept-theory development (Yin, 2011). Open-ended coding enabled the development of broad categories from the raw data. This data was structured to analytically present student experiences, transformative incidents, and ongoing dilemmas. This form of thematic analysis led to the condensation of meaning from the lived experiences of students and teachers as co-learners in C-Lab.

8.3 An exploration into challenge framing

> *I have often wondered where I fit in academia and what role I can be valuable in later on in life beyond my engineering education. However, I have always come short of figuring it out. I know that I quite a few times, albeit not very eloquently, have expressed that I enjoy solving problems, that I enjoy more regarding the big perspectives and that I often tend to move from a certain detail that I study to it impacts on society and*

other greater levels. I also know that I have described a few times that I tend to sub-consciously identify processes and the likes around me that has locked up potential, there is something great to it but it is inhibited, quite often by a stupid detail like a bottle neck that I seem to be able to point out. Too often people are annoyed by me doing this or simply don't seem to understand me. When I reflected about this during the week, I did at one time describe that for me to enter into the Challenge Lab was some sort of an "epiphany", I maintain this, it is a good description. It seems to me now, to a lot of relief that there is this area of systems thinking, learning, engaging in dialogue, multi-disciplinary work and envisioning a different future is something that fits pretty well together and comes together in a discipline. I find myself very much at home in this spot.

Student reflection, C-Lab course 2020

Paper II established a basis for understanding learning environments as concerned with complex sustainability challenges. In contrast to both the solution-driven nature of many courses, as well as the notions of problem-based and course-based learning, challenge-driven learning environments recognize both the complex nature of the issues at hand, as well as the need to rethink our capacity to resolve them. As an ambition of this space, challenge framing is not predictive, but rather performative; throughout an unfolding process, framing processes shape the relevance of certain issues, directing attention, influencing value and goal setting and structuring an understanding of progress, success and failure (Schön, 2008; Ison et al., 2010). It did this with the view that challenge framing provides a boundary object[36] for transformative praxis, where sustainability is held to be complex and contextual.

By exploring the interplay between intention, enaction and experience in a challenge-driven learning environment, paper II presents four sets of thematic experiences. First, students experienced that in C-Lab there was room for learning about what it might mean when we frame complex sustainability challenges. This experience manifested in how students threaded connections between real-world challenges and their own capacities and backgrounds.

[36] "*Boundary objects are objects that: both inhabit several intersecting worlds and satisfy the informational requirements of each of them. . . [They are] both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual site use*" (Star & Griesemer, 1989, p. 393).

Second, we organized experiences regarding the shift from problem-solving to challenge-framing within the course for students and teachers. This included the tendency from students to retrofit pre-conceived solutions to a problem context, resulting in incremental suggestions for complex challenges. This presents a dilemma where students with both an awareness of their tendency to retrofit, combined with their ambition to engage with systems change, recognized a discrepancy between knowledge and action. Moving from problem-solving to challenge framing is an emotional process for both students and teachers. In early stages, this is expressed via a sense of fluffiness in course content and direction; limits to knowledge become visible when reconstituting complex systems; deeply held assumptions about change are brought into friction with the open-ended nature of systems change. As the course develops students create a collective capacity for staying with complexity and making directed choices.

Third, and relatedly, students begin to experience that solution-orientations are no longer sufficient in moving forward in systems. In this stage there is a strong sense of feeling stuck, and yet, and the same time, feeling uprooted. When faced with systems that grow, a sense of progress in content is halted; during this standstill, students begin to reflexively engage with their own knowledge bases. By moving forward, progress begins to take on a qualitative novel character, where what it means to "progress" expands. Through student and teacher experiences, this moment signals a profound transformation in the purpose of the course for those inside it; a moment where students realize that they can abandon their solutions and approach their learning space in a different manner.

Fourth, challenge framing processes raise questions regarding the nature of progress in the course. On the one hand, students experience uncertainty regarding progress in their learning, frequently turning to eachother and to us as gauges for where we are. On the other hand, course designers are grappling with their own views of a "successful course" flow, while trying to provide affective support without reducing the possibility for self-directed learning. We also notice how this space is influenced by dominant frames of time in education, where linear and structured flows dominate.

In addition, this paper also illuminates the uncertain nature of teacher-as-learners in navigating challenge framing processes. The relational nature of this work encounters pre-conceived notions that students and teachers have of eachother. As course designers, we reflect upon the dilemmas that accompany challenge framing processes. This includes mismatches between the time needed to bring such challenges into being, versus the time provided during courses; the moments where the learning impulse for strong direction may misalign with course design; when we introduce problem frames from stakeholders into the course, recognizing that this may skew the progression of the course.

Interestingly, as designers are asking ourselves similar questions to students: As facilitators, we ask ourselves: What is progress here? What is enough to move forward? How do we know that we are in the right stage? Is discomfort and frustration desirable or undesirable? Do we need to adjust expectations? These reflective questions provide the context for collectively approaching complex challenges and sharing them provides a basis for trusting through discomfort.

9 Phase three: Evaluating labs in relation to transitions

> *We all know that the caterpillar will be metamorphosed into a butterfly. But does the caterpillar know that?*
>
> *Beck, 2016, p. 13*

9.1 Arriving at research phase three

My third research phase may be the most recent research phase in this doctoral journey. Yet, questions of evaluation are age-old, connected to the fundamental instinct of anticipating the world around us. This phase broadly concerns what Sayer calls our "evaluative orientation" as humans, whose relation to the world is one of concern (2011). Whilst Sayer writes primarily of the evaluative experience of everyday life, his work can be seen as a response to the sterilizing impacts of both social and natural science in attempting to better understand social matters of concern. Spectator-modes of evaluation, routinely seen through a disciplinary lens, present descriptive accounts of social situations that are disconnected from the lived realities of those involved (Sayer, 2011).

By framing evaluation as a relational practice, by humans who care, Sayer and others provide a language for making sense of transformative change as part of an ongoing act of experimenting. In the context of sustainability transition experiments, such as labs, the importance of evaluation cannot be understated. Labs are experimental, learning-oriented activities. They are strategic attempts to engage with long-term change via experimental processes in the present. As highlighted in research phase one (Chapter 6), labs regularly engage with participatory process development, as well as explicit engagement with futures. At the same time, transitions and transformations imply scales of change that dwarf labs and transition activities. Threading together the intents, processes and outcomes of labs within complex and uncertain systems therefore suggest that novel and experimental forms of evaluations are required.

These considerations therefore raise a series of "how" questions associated with evaluating labs and transition experiments. Questions such as: How can experimental evaluation be seen as part of a plural space of possibility? How can designers, participants and evaluators reconceive of, and rethink, evaluation as a leverage point for more transformative praxis? How can we think together about how to act, in a way that can be communicative,

developmental and learning-oriented? How can we develop evaluative orientations that enhance the agency to act in context? Such questions, as well as the methodologies that they promote, are considered crucial in ongoing scholarly engagement with evaluation in transitions and transformations (Pereira et al., 2019; Williams, 2019; Hölscher et al., 2021; Luederitz et al., 2017).

Research phase three began with sustained theory-practice conversations on the broader topic of evaluation for sustainability transitions. It emerged out of the realization that more can be done to better understand evaluation and its capacity in supporting labs at the level of design. This included the need to carve out relational spaces, where approaches to evaluation can be exchanged in a way that can better equip future research and action. This research phase is therefore motivated by four collective ambitions. *First*, an ambition to thread together evaluation and transitions by considering evaluation practices in transition experiments. *Second*, an ambition in building possibility to explore, compare, and learn from approaches to evaluation that are issue-driven and post-disciplinary. *Third*, an ambition to create spaces that can uncover tensions and challenges that resonate with practices of evaluating transitions to sustainability. *Fourth*, an opportunity to bring together practices that ran through all research phases, as well as ongoing praxis in C-Lab. With the above ambitions, phase three was guided by RQ4:

RQ4: What is the capacity of evaluation practices as a tool for sustainability-oriented labs?

9.2 Methodological approach for phase three

Within research phase three, the purpose of paper IV is to explore, understand the capacity of evaluation, understood as a meaningful social practice, within transitions and transformations. Its research purpose emerged from sustained conversations and structured reflections with evaluation designers of three labs and transition experiments. Its intention is to highlight the diverse and distinct approaches from such experiments, and the way in which they attempt to transgress conventional challenges with evaluation. The experimental nature of these sustainability transition initiatives such as labs, institutions and projects, coupled with their commitment to systems change, provide an ideal empirical context for fostering and sharing knowledge on evaluation.

Methodologically, this study employs an illustrative case study/instrumental case study comparison (Stake, 1995). The choice of cases was taken to enable maximum variation in

insights (Flyvbjerg, 2006). Maximum variation cases enable a spectrum of empirical instances to be investigated and potentially compared. To clearly demonstrate the variety of approaches to opening evaluation, we selected three illustrative examples. Each case is distinctive in terms of context and approach to evaluation. We do not present these as comprehensive case studies here but instead focus on how their perspectives on evaluation provide an entry point into how each example has approached 'opening up' evaluation. By maintaining diversity, rather than reducing it, these cases occupy a field of difference, where each can be understood as contributing towards experimental evaluation practices.

Through sustained conversations and process reflections, a three-part analytical frame was co-produced by evaluating partners: (1) exploration of a specific challenge with the evaluation of transition initiatives, (2) a descriptive account of each transition initiative in relation to a given challenge, and conceptual grounding, and (3) case-specific reflection, based on experience harvesting and reflective conversations. Its intention was to serve as a provisional frame for engaging in partly structured reflection on respective cases. These reflections required a re-entry into the empirics of each evaluation practice. In addition, by combining this reflection with both immanent and emergent reflections, it became possible to search for resonant themes that appeared from each case yet remains irreducible to each.

9.3 Comparing evaluation practices

In paper IV, we identify three challenges in the literature regarding evaluating sustainability transitions experiments, namely (1) the partial nature of evaluation, (2) the "who" of evaluation, and (3) the challenge in linking labs and experiments to broader systemic change processes.

We illustrate responses to each evaluation challenge by way of three cases:

1. **Challenge Lab North Middle Sweden (C-Lab NMS):** An experimental pilot in North Middle Sweden in 2020/2021, organized around backcasting-from-principles, which sought to develop new tools for regions and cities.
2. **The atmospheric fund and city of Toronto (TAF):** A collaborative evaluation process in 2018-19, between multiple stakeholders and community-led projects organized around climate mitigation and adaptation goals in Toronto, Canada.
3. **The institute for advanced sustainability studies (IASS):** An institutional attempt by IASS in 2022, based in Potsdam, Germany, to engage in evaluation that could measure, capture, and communicate sustainability transition impacts.

Challenges concerning evaluation

First, *the partial nature of evaluation* brackets crucial dimensions of an attempt to learn amongst uncertainty (Reed et al. 2010). Within evaluation practices, this appears as a pre-defined and fixed set indicators for understanding success. Such indicators are often oriented towards future impacts of an activity, preserving a boundary between experiment and the real world. Rather than unfolding processes in context, partial evaluations reduce lab and experiment impacts to afterthought.

Second, *evaluation practices limit the "who"* of evaluation. For example, limited forms of evaluation can occur in the understanding of how learning can take place across a wide base of stakeholders in different ways. It can also take place when evaluators make decisions on how to go about their practices. This challenge highlights the implied power in the practice of evaluations in making judgements on experimental initiatives, and whether evaluations are internal or external to their intended learning (Miller & Campbell, 2006).

Third, evaluation practices *limit the dimensions of change* that might be understood to occur within experimentation. With the highly projectified nature of labs and experiments, evaluation practices are often equipped with frameworks for understanding observable, short-term impacts. In the context of larger systems change, there is a growing need to balance intended with unintended influences of labs (Williams & Robinson, 2020). Moreover, pressures to assess the immediate impacts of activities may mean that time and attention is not directed towards the emergent interactions that they often encourage. As highlighted, these pressures are connected to the governance of experimentation, where the expectation that one remains accountable to funders, remains.

Case reflections

When responding to the problem of *partial evaluation*, the concept of social learning and process learning supports in understanding evaluation as dynamic rather than static. Whereas partial evaluations may constrain initiatives for transitions at an early stage by predefining "successful" outcomes, learning-oriented evaluations may allow new ideas to emerge as part of a dance within changing system conditions. By engaging in C-Lab NMS an example of learning-oriented evaluations, we reflected on the importance of evaluation in surfacing elements of process that sit above single tools and methods. Second, we explored the possibility of evaluation in strengthening the links between ongoing labs and broader systems.

Whereas practices often limit the *who* of evaluations, literature on *empowerment* points towards the possibility of shifting power dynamics in the pursuit of just and equitable

systems change. The case of the atmospheric city fund in Toronto made it possible to explore tensions that might occur when considering questions of participation and the "who" of evaluation. Reflections on the TAF project included the presence of co-developed evaluation principles that created shared ownership over the things that might matter. Here, rethinking questions of "who" in evaluation therefore made it possible to develop impactful processes alongside evolving evaluative design.

In the case of limiting impact to *short-term activities*, the evaluation of IASS directs attention to the *institutional moments* where conflicting views on evaluation can come into context with one another. In the case of a national evaluation process of IASS by the national research council in Germany, there appeared to be a mismatch between the ambitions of TD research within the institution, and an expectation of impact from the national science council concerned with a transfer-and-translate model of knowledge. Although IASS highlighted that its integrative work focused on societal challenges and TD challenges, it was actively providing alternative frameworks for evaluating their own institutional missions that could shift conversations at the national level. This tension is crucial in directing attention towards certain elements of experimental research and practice; in this example, the reliance on traditional research measures reduced the scope for learning about broader transition impacts that are often associated with such activities. By making use of transition impact evaluation as a tool that links transition processes to the broader systems in which they are embedded within, it might become possible to understand the interplay between experiments and transitions for a broader transformation towards sustainability.

In conclusion, these three case-based reflections point towards the need to search for and nurture evaluative approaches that are appropriate for transitions experiments. Our intention is to highlight the diverse and distinct ways that evaluation can be approached within such experiments, and the way in which they attempt to counter conventional challenges. Rather than implying that the above challenges and cases are mutually exclusive, we seek to exemplify how both manifest in evaluative work, as well as how they might be re-conceived for more transformative praxis.

Part Four: From parts to a whole

In **part four,** I attempt to thread together all papers in response to the overall aim of this thesis. In **Chapter 10,** I begin by searching for cross-cutting insights from all research phases, before reflecting on the limitations of each phase. I then present a series of contributions from this thesis and the studies contained within (**Chapter 11**).

10 Crosscutting themes across appended papers

10.1 Inner dimensions of change

Scattered across this thesis are fragments of lab insights, case-based experiences and practices that highlight the inner dimensions of transformations. There is a growing sensitivity to inner dimensions of change, as well as an attention towards the view that change "in here" is interrelated to "change out there". Inner work, understood as concerning the inner dimensions transformations, attempts to grapple with forms of alienation and separation that have come to constitute everyday life (Woiwode et al. 2021; Vogel & O'Brien, 2022). Given the contested nature of sustainability issues, action-oriented forms of science embrace the need to elicit and work through values as a precondition for deeper forms of change (Fazey et al., 2018; O'Brien & Sygna, 2013; Bradbury et al., 2019). Inner work is not only an end, but also a means towards more transformative forms of leverage, where it can: (1) broaden value bases, (2) elicit conflicting values in the development of direction, and (3) produce robust forms of innovation (Rosenberg, 1982).

Inner work has various roles to play in lab praxis. In paper I, we emphasized the importance of spaces, processes and ways of organizing around complex sustainability challenges. At the process level, from paper III, it is possible to say something about the possibilities of inner dimensions of sustainability based on lab practices. Within our empirically grounded typology, inner work can be seen in types *Educate and engage, Empower and govern* and *Explore and shape*. This included labs that actively engaged with the exploration of shared values (Charli-Joseph et al., 2018) or guiding principles (Larsson & Holmberg, 2018). Engaging with contested topics through process may also actively seek to surface divergent values as a source of tension relevant for learning (Engeström, 1987).

During time in C-Lab (paper II), the importance of the inner dimensions is visible in how sustainability challenges unfold. This includes how participants in C-Lab begin to thread connections between their current forms of education, inherited training, their lived histories, and capacities for making change. As designers, we explicitly frame in the lab that students possess an immense capacity for change, that their position in society can be understood as crucial, and that within this lab we will look inwards to enhance learning together. Moreover, we illuminate the dilemmas that educators-as-co-learners navigate as matters of educational praxis. As matters of praxis, these learning spaces provoke ongoing reflection at the level of pedagogy, including (1) a critical appraisal on our own levels of practice, (2) an evolving understanding of the structure and nature of learning spaces, (3) a

dynamic interplay between comprehending and progressing in learning spaces whereby reflection in settings is transformed into action. The development of reflective capacity is considered crucial in transformative educational approaches that move from first-order towards third order learning (Holdsworth et al., 2013; Sterling, 2001). This study indicates that such capacities are internal to challenge-driven environments such as C-Lab.

These findings complement existing research on C-Lab that highlight how guiding values and principles support students in linking the inner and outer dimensions of change in a relational manner (Holmén et al., 2021, Holmberg, 2014). In addition, the introduction of dilemmas – not owned by teachers or students but emerging as contradictions within learning space – connect to the relational and affective implications of grappling with complex sustainability challenges in education (Akkerman et al., 2021; Jickling et al., 2021; Vogel & O'Brien 2022). They speak to mismatches between the time needed to bring such challenges into being, versus the time provided during courses; the moments where the student or teacher impulse for strong direction may misalign with course design and emergent outcomes; and when we introduce problem frames from stakeholders into the course, recognizing that this may skew the progression of the course.

Inner dimensions of change are argued to deepen the learning process through supporting shared awareness and collective actions (see e.g., Brundiers et al. 2010; Wamsler & Brink, 2018; Charli-Joseph et al. 2022). Regarding the topic of evaluation, the notion of inner dimensions of change raises daunting questions around whether it is helpful to understand evaluation as an analytical exercise, or as a series of social practices centred on upgrading learning. On a broader level, considering inner work in labs surfaces the uncomfortable view that academic forms of knowledge may present obstacles to deep change, and that researchers may need to learn to live within complexity in a manner that mirrors their expectations of other stakeholders (Cillers & Prieser, 2010; Ison, 2010). Researchers (myself included), research designs, and lab intents may well benefit from approaching the possibility of transcendental change (Vogel & O'Brien, 2022; Mozer & Fazey, 2022; Sellberg et al., 2021).

10.2 Labs as systemic inquiry

There is much to say regarding systems thinking, its influence on this thesis and the positions that it can occupy moving forward in transformational change processes. As indicated in chapters 4 and 5, there is a natural complementarity between the ambitions of systems practice and the view that transitions and transformations concern complex systems where radical change is required (Loorbach, 2022). Connected to papers I and III,

organizing several discourses around sustainability-oriented labs are explicitly systemic at the level of process and intent. These include Evolutionary learning labs as a systems-based approach to complex issues; Urban transition labs that engage with governance of systems change; Change Laboratories and their intent towards the transformation of cultural activity systems; T-labs that experiment within novel social-ecological-technical systems. Systems thinking takes different forms in terms of influence here. For some, a particular sub-thread directly feeds into the epistemic basis for its work. For others, processes carve out a space for "understanding systems" as part of a larger meta-methodology (Nevens & Roorda, 2014).

In paper III, various lab types provide nuance as to how systems can practically be engaged with. *Fix and control* labs are implementation and evaluation-focused, displaying little, to no, evidence of engaging at the level of complex systems or futures. Systems are technical and complicated, and in some way not to be perceived at all. Implementation is largely consigned to technological installation, testing and measurement. *Make and relate* labs are self-organizing at the level of process, reliant on organic interactions across stakeholders with a shared intrinsic motivation. *Explore and shape* labs have rigorous methodological approaches around complex sustainability challenges. Tools are oriented towards understanding the complexity of present systems, as well as widening the perspective involved in shaping these understandings.

In C-Lab, systems thinking plays two roles within both educational and broader TD settings. First, within the space, the need for systems innovation is an initial framing choice. It highlights that unsustainability is a product of intersecting systems in society. Second, systems interventionism forms the basis for the second step of a backcasting from principles approach. Here, it provides the possibility of organizing systemic situations as possibilities for learning. The role of situations provides a contextual entry point for moving deeper in systems. Connected to applied critical realism, heuristics such as the iceberg model, are recruited iteratively, whereby the movement beyond empirical events develops co-produced knowledge around patterns of behaviour, structural elements of system and the narratives and myths that shape how they are articulated (Davelaar, 2021). This is then complemented with sociotechnical systems mapping to collectively sense how systems are configured and incumbency ensured. C-Lab participants engage in leverage points thinking as a heuristic for approaching systems purposefully, marking the movement from challenges to opportunities. It signals the moment when the collective creation of new configurations can be explored in search of transformative potential.

10.3 Futures unknown are futures unshown

This thesis has been written at a time when time matters more than ever before. Amidst the urgency associated with large scale transitions and transformations towards sustainability, there is a compulsion to accelerate change in a way that "*forces people, organizations, and governments into a reactive situational attitude instead of a self-determining conduct of individual and collective life*" (Rosa, 2013, p. 295). Here the dominant narrative is that time is linear and uni-directional; it is running out; the future matters more than the past, and we need to use what we 'have' to react to current situations (Alhadeff-Jones, 2017; Priebe et al, 2020).

In the context of sustainability, mainstream responses to the future tend to follow a predictive logic (Andersson, 2018; Patterson et al. 2021; Dreborg, 1996). Here, extrapolations of historical trends are carried into the future, providing frames of reference for what is most likely at hand (Muiderman et al. 2020; Anderson, 2010). The negative time associated with climate change conveys the message that time is running out and that rapid change is necessary but provides little direction on what and how things can change (Markard et al. 2020; Van Beek et al., 2020). At the same time, they "*lead us to believe that our agency in the present is reduced to quick responses that override democratic, deliberative, and local options in order to avoid tipping points*" (Priebe et al. 2020, p. 7). In recent years, trends have broken, signifying our incapacity to predict our way forward in an era of unprecedented change.

Given that predictive logics tend to downplay potential for qualitatively different change within open systems (Patomäki, 2006), experimental approaches to sustainability call for something entirely different. They advocate for the meaningful co-ordination of change that is underpinned by diverse forms of engagement with the future (Stirling, 2009; Scoones et al., 2015; Frantzeskaki, 2018). They are part of a swelling sentiment that the roles of temporality are not one, but plural, when engaging with sustainability, and that its value may lie in how it provides a source of imagination and creation (Brown et al. 2010). Recent calls from within sustainability transformations have therefore shifted attention towards futuring as a way to elicit, explore and co-produce futures (Bai et al., 2016). One source of development concerns their anticipatory and directional characters. Drawing from various fields such as systems theory, educational sciences and futurology, anticipation and direction adopts a multifaceted view of the future[37] (Anderson, 2010; Amsler & Facer, 2017;

[37] Anticipatory attempts to engage with futures include: (1) Engaging in reflection on futures (Hebinck et al., 2018), (2) Developing a shared understanding of desirable futures (Larsson and Holmberg, 2018), (3) Participating in the making of alternative futures (Anderson, 2010; Muiderman et al., 2020), (4) Linking inner

Pel et al., 2020). Not only are possible futures plural, but "*the most likely futures may not be the most desirable*" (Robinson, 1988). Rather than reacting to the probable, navigating uncertain terrain requires an expanded realm of possibility, where plural conceptions can provide a basis for action in the here and now:

> *Coordinated actions anticipating possible futures, whether real and concrete or illusionary, shape the present and thereby also contribute towards the materialization of a particular line of development in world history*
>
> *Patomäki, 2006, p. 29*

Across the studies from Phase one: Sustainability-oriented labs in real-world contexts, papers I and III brought into view of sustainability-oriented labs as directionally conscious activities (Pel et al., 2020). Process-oriented approaches imply the presence of single or multiple futures, as well as the capacity to experiment with alternatives. For make and relate labs, their prefigurative nature implies a collapse between past, present and future, with a focus on making in the present. We highlighted that explicit, process-based engagement with futures resembles more conscious directional work; implementation-focused activities, such as those present in Fix and control labs, methodologically and epistemologically restrict the space for futures and arguably represent weak directional work. In addition, purpose and direction have often been articulated in advance of their processes. In other words, they take for granted what is needed to be done. This closure limits the option space to lower levels of learning.

Feola (2020) contends that engagement with directionality in place is underpinned by engagement with futures at the level of the process. *Educate and engage, Empower and govern,* and *Explore and shape* labs, on the other end of the typology, emphasize forms of participation in developing a collective sense of direction to internally guide lab activities and outcomes. This sense of direction can be situated at multiple levels, including: (1) the individual or intersubjective level, (2) at the level of lab, (3) at the level of larger system (4) in between lab and system.

The incorporation of a directional perspective into labs is crucial as reflexive governance processes influence transitional change by strategic action in the present (Voss & Kemp, 2005; Yang et al., 2021). These labs begin by orienting around a complex and contested

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and outer dimensions of sustainability through futures (Fuller & Loogma, 2009), or (5) Performative, embodied approaches to the future (Vervoort et al., 2010; Stripple et al., 2021).

challenge, which may require alternative perspectives and new framings. Inherent in challenges is epistemic uncertainty regarding the ability to know the future, combined with a willingness to search for possibility. Their methodologies include futuring techniques such as envisioning, scenario analysis and backcasting. Methodologically, a common way of sequencing the movement to the future begins with first developing a systemic understanding of the present before exploring futures (Quist, 2007).

Paper II concerns a course curriculum structured around backcasting. As part of C-Lab, principles-based backcasting[38] provides a meta-methodological framework for engaging with desirable futures. Ontologically, from a realist perspective backcasting considers the world as one of possibility (Patomäki, 2006), where there is structural plasticity in terms of what it can be. It is real yet undetermined, emphasizing the importance of actively articulating futures to shape them. Epistemically, it specifies a way through which the future can be known. In the case of C-Lab, guiding principles provide a basis for conversations around desirable futures (Holmberg & Larsson, 2018).

Principles instil a sense of shared direction that can maintain an interpretive flexibility whilst at the same time encouraging deep forms of learning. Principles provide guidance to mobilize in the here-and-now, where backcasting sequences learning processes from future-present towards points of leverage and experimentation of alternatives. By sequencing principles before systems understanding, it attempts to think beyond present systems by beginning with future desirability. Axiologically, backcasting rests upon the view that there is a need for major change at the level of systems (Dreborg, 1996). It views this change as something that can be created together, that can be dreamt and imagined, and whose substance can provide guidance for action in the here-and-now:

> *It assumes that both vision development and pathway development encompass processes of higher order learning, in which participants learn not only about preferable futures and their contradictions, but also about the present, about each other, about barriers and incentives, about the change agents, and about how to improve the future vision to make it more appealing and resilient.*
>
> *Vergragt & Quist, 2011, p. 749*

[38] Backcasting distinguishes itself from futuring processes that attempt to calculate probable futures, as well as those that are centred on plausibility as a basis for deliberation (Vergragt & Quist, 2011; Muiderman et al. 2020). Rather that calculating what is likely to happen, or exploring what could happen, backcasting deliberates what should happen as a matter of desirability. It is overtly normative, participatory and anticipatory, yet action-oriented (Robinson, 2003; Homberg & Robert, 2000).

Within C-Lab, backcasting from principles provides a structure for students and teachers to inhabit a challenge space. This has at times been an uncomfortable space for students, as highlighted in paper II:

> *Even with agreement on the importance of a backcasting procedure in framing challenges, students often become uncomfortable and overwhelmed. In initial weeks of the course, some (including those who experience principles-based engagement as providing purpose and direction) perceive not only the content as fluffy or abstract, but also a delay to their engagement with "more concrete" stages.*
>
> *McCrory et al. 2021, p. 7*

Its value may lie in how it attempts to overcome the fatalism triggered by complex sustainability issues with the hope of imaginative practice. Recent attention has turned to the transgressive potential of backcasting in its attempt to break free of (1) the tyranny of the present and overreliance on prediction, (2) the overwhelming and disarming nature of complexity at hand, and (3) how to navigate levels of leverage that bring transformative potential in contact with capacities to act (Holmén & Holmberg, 2022).

Regarding the evaluation of futures that are-in-the-making and yet to be realized, one might ask: how do we even know which direction they are moving in? This question is by no means new, but it is profound. It lies at the heart of ongoing praxis in experimental approaches to sustainability. While researchers and practitioners have cultivated a rich set of methodologies for lab processes (Pereira et al., 2020; Mukute et al., 2018; Schäpke et al., 2018; Charli-Joseph et al., 2018), less can be found regarding engagement with the indeterminate nature of the future, as well as the unprecedented nature of change at hand. This has two impacts on lab practices. First, is means that researchers and practitioners must remain humble to claims regarding the implications of engaging with the future, as well as the ontological limits of this. Second, it means that evaluative praxis is, in some way, searching in dark for complex traces of impact, whilst at the same time knowing that transformations imply an essentially speculative logic to the act of experimenting.

Paper IV began and finished with the modest view that the future remains essentially unpredictable. Yet, one of the central premises is that transitions experiments and labs may have multiple roles to play in anticipating desirable sustainable futures. As a matter of praxis, evaluators are evermore embedded in experimental design, enabling a collective and communicative approach to understanding change in context. This is evident in the range of developmental and formative approaches to evaluation that are being adopted (Pawson & Tilley, 1997; Gamble, 2008). Moreover, they are challenging pre-conceived notions of what it means to co-produce actionable knowledge, and how/when this can be shaped. This is

evident in evaluative approaches adopted in citizen science, student-driven and emergent approaches adopted in educational environments (Wooley et al., 2016; Moser & Fazey, 2021; Ishihara et al., 2021), and evaluation frameworks that attempt to extend the remit and position of the evaluation in experimental activities (Williams and Doyon, 2020).

The logics that therefore underpin evaluative praxis have an important role in the unfolding of labs, as well as their eventual impacts within systems. Resembling ripples within a complex network of relations, the impacts of experiments within systems require approaches to evaluation that are equally adaptive and reflexive, yet humble. Paper IV highlights how mismatches can occur when the evaluations are partial in terms of what, limited in terms of who, and narrow with regards to labs in systems. It highlights how, by engaging with experimental forms of evaluations with logics that reflect the adaptive nature of these processes, and the uncertain nature of futures, alternative lines of inquiry become possible. In addition, this paper points towards two important topics in the governance of sustainability transitions and transformations: (1) the possibility of evaluation practices that can support ongoing processes, reflecting the purposeful nature of these activities, (2) and the need for evaluation practices that can further the search for qualitative systems change by considering labs within a broader ecology of experimentation over time and space (Pereira et al., 2018; Kok, 2022).

10.4 Labs and education

Running through this thesis is an explicitly educational thread; *Educate and engage* labs appeared in phase one as disruptive, experimental activities located at universities. They belong to a larger movement [39], where educators are actively experimenting, *in, through,* and *with*, universities, in search of new ways to increase the relevance of education for society:

> *Educate and engage labs include real-world university approaches to teaching and learning sustainability. These educational environments, located at university campuses, focus on rethinking university-society relations by engaging students in experiential, action-oriented learning. Institutionally, they frequently counter conventional approaches to education for sustainable development that are teacher-centred, lecture-based and disconnected from real-world application. Educate*

[39] Faculty for a future: https://facultyforafuture.org/; Centre for unusual collaborations: https://www.unusualcollaborations.com/ Bildung academy: https://en.debildungacademie.nl/; Eco-school and eco-pedagogies: https://www.ecoschools.global/

> *and engage labs experiment with new forms of collaboration, material constellations, learning environments and curriculum designs. One shared goal is to support students in engaging with situated challenges, often around a specific thematic or topical focus, where educational curricula are woven into real-world situations.*
>
> *McCrory et al. 2022, p. 105*

C-Lab took centre stage in phase two through qualitative case-based engagement. As this PhD progressed, the meaning of education grew much more than I could have imagined. It moved from method to axiology. In truth, I was gripped by the approach to learning in C-Lab. It struck me as an incredibly human space. There was little talk of infrastructure, subjects, exams or laziness. Yet there were serious conversations around what a learning environment can be, how to practice integrity, which knowledge matters, how we can approach and understand learning, and the affective dimensions of education. As part of my own development, C-Lab has existed as a space to learn about facilitation, process development and network building. Along the way, what became clearer to me that it also provided a space of hope-through-practice for students and designers who chose to devote their time there.

During my time in C-Lab, I sensed that commitment springs from a feeling that the current forms of education, often technical in nature, left students thoroughly unprepared for responding to ecological and social challenges. It marked the continuation of soul searching, together rather than alone, when knowledge seemed to leave us incapable of acting. For some, C-Lab provided a reference point to compare with ongoing courses. It triggered self-reflection and introspection into what it might mean to become a change agent. For others, this time in C-Lab was marked with grief at what could have been, the joy of names that were remembered, the laughter of creativity, the sadness that opportunities were missed. I am reminded of the words of Parker Palmer that:

> *Education at its best—this profound human transaction called teaching and learning—is not just about getting information or getting a job. Education is about healing and wholeness. It is about empowerment, liberation, transcendence, about renewing the vitality of life. It is about finding and claiming ourselves and our place in the world.*
>
> *Quoted in Hooks, 2013, p. 42*

C-Lab was also a place where the highly uncertain nature of sustainability issues generated deep discomfort and confusion. Realizing that systems are complex; futures plural; facts uncertain and values at stake, can disempower. For designers and facilitators, its pedagogy

encouraged us to think through and practice around what it might mean to share education. It forced us to acknowledge that we might also need to learn new things and *unlearn* our tendencies to control, whereby:

> *Under conditions of uncertainty, the educational task is, in principle, not an epistemological task; it is not one of knowledge or even knowing per se. It is not even one of action, of right and effective interventions in the world. For what is to count as a right or an effective intervention in the world? […] the educational task is primarily an ontological task. It is the task of enabling individuals to prosper […], amid a situation in which there are no stable descriptions of the world, no concepts that can be seized upon with any assuredness, and no value systems that can claim one's allegiance with any unrivalled authority.*
>
> *Barnett, 2004, p. 253*

In this discussion, I hope to have threaded together threads that crosscut this thesis. These have included the inner dimensions of change; the systemic nature of challenges at hand; considerations of time, and the connections between labs and education. Knowing that convergence is always around the corner, I view these threads as points from which openings may appear, rather a closure of what has happened and how papers may interconnect.

10.5 Reflection on limitations

As outlined in the introduction, this thesis is interested in how labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformations. In all three research phases, there are important limitations that are worth reflecting upon (Table 6). From a praxis perspective, limitations are not merely statements of what has been the case. On the contrary, they provide a way to learn about learning, to make peace with what we have done based on what we tried to do, and to develop for the future.

Research phase one: Sustainability-oriented labs in real-world contexts

The empirical material underpinning research phase one is derived from secondary sources. Although our intention was to remain open to research scopes and objects, we rely across both papers on peer-reviewed articles, as well as selected books, to say "something" about the phenomenon of labs. We do this with the assumption that these sources ensure a degree of credibility and authenticity in how they portray their cases. The use of secondary

sources in qualitative synthesis processes has drawn both encouragement (Clark, 2016) and criticism (Dixon-Woods et al., 2006). On the one hand, it provides a way to search for patterns of meaning. Secondary sources also make it possible for us to sidestep the process of bounding each lab empirically, as this decision was made by primary lab researchers. On the other hand, secondary sources create a form of empirical and interpretive lock-in, whereby absences of other cases may feed into our own methodology.

Such absences likely include that (1) everyday forms of experimentation not mentioned as "labs" remain absent from this work, (2) although forms of experience and ways of knowing are often bound up in lab practices, there remain difficulties in reflecting this in casework, (3) although focusing on articles, conference proceedings and book chapters, excluding grey literature, handbooks and visual material may reduce tacit knowledge to academic knowledge, and (4) in engaging with labs as an object of study and relying on secondary sources, this research strategy involves a triple movement of interpretation.

Triple interpretations take place when synthesising a collection of complex qualitative cases into a sample. Here, I am mindful of our inability to "*have a full understanding or appreciation of the context in which the research interactions take place*" (Weed, 2005, p. 12). Despite this limitation, triple interpretation was both expected and grappled with during Papers I and III. Methodologically, we held a transparent and reflexive approach during the review process, spanning over two years and across dozens of meetings. We incorporated multiple reviewer checks, engaged with data in contact with initial sources and engaged in reflection sessions to situate ourselves within our research process.

As with levels of interpretation in qualitative research, generalizable claims to knowledge become less possible as it becomes more likely that findings are decontextualized. At the same time, the intention of a qualitative review process differs from those that accumulate knowledge on a specific topic, where best practices are to be generated. These practices were central in a broader effort to build reflexive capacities within our research group, considered necessary for lab research and praxis. Our goal was to reach new levels of meaning or patterns that transgress discourse labels, only possible through triple interpretation, whilst remaining humble about the limitations of this.

Additionally, these studies aimed to direct more attention towards notions of sustainability. Papers I and III have made contributions towards this by bringing together, unpacking and classifying a collection of labs that share this commitment. In exploring how these labs relate to one another, it has been possible to differentiate meanings of sustainability that exist in place, as well as indications of processes that attempt to grapple with sustainability. At the same time, we view sustainability as a dynamic property within labs, often mobilized to establish significance surrounding a matter of concern and providing a frame for various

forms of interactions within this space. Knowing this, we contribute modestly towards sustainability in the context of a systematic review process, whilst acknowledging that intensive research approaches may be required to investigate the contextual dynamics of sustainability through process.

Research phase two: Learning to frame complex sustainability challenges

The limitations for research phase two have been challenging to trace, given the emplaced nature of this work. For me, it has been helpful to understand that multiple agendas co-exist within the learning environment. There was an ambition to develop, sustain and foster an experimental learning environment within an institution that is geared towards efficiency. I held an interest in engaging in research that could be relevant both for the academic dimensions of a PhD, that demonstrated novelty as a research piece and that could be useful in enhancing educative capacity. At the same time, I was continuously navigating C-Lab as a designer and co-learner with both students and other designers. My well-planned research ambitions were continuously encountering the everyday messiness of educational settings. These settings were in turn throwing a stream of rich insights and learning situations that feel important all the time, because they matter.

Being emplaced in a setting such as C-Lab demonstrates the messiness of qualitative research that is action-oriented. If you pursue a topic that you feel is relevant but disconnected from praxis, you risk generating insights that cannot feed into this work. If you are swept up in the everyday learning environments, you risk under-developing in favour of solving practice problems, at the expense of conceptually or theoretically enriched work. If you overcommit to solving practice problems, you may never ask whether they are the right problems to solve, or whether they were even problems as all. If you commit too early to sensitizing ideas, you risk focusing on previously established gaps rather than emerging insights. The main limitations of phase two related to the embedded nature of this research phase in combination with the need to maintain reflexivity of self-*in, with and through*, case.

Despite the advantages presented regarding empirical windows, there is a degree of uncontrollability when making positioning decisions. Paper II coincided with multiple crises that directly impacted C-Lab, its everyday praxis, the student experience, and my ability to position myself empirically. In 2020, the ongoing COVID pandemic moved all teaching environments online; C-Lab experienced organizational challenges through the loss of a central member of the core design team; students experiences in C-Lab were intersecting with a highly uncertain and troubling period in their educational and personal lives. These experiences are in no way limited to the student and were deeply felt by designers and

educators. It might be so that the interest in dilemma stemmed from the contradictions that we were facing within this learning environment; they provided a window for us to embrace uneasiness, at a time that was particularly uneasy for some of the reasons described.

Research phase three: Evaluating labs in relation to transitions

Two limitations are important to note regarding research phase three. First, this research design requires a high degree of reflexivity to provide authentic insight for action-oriented knowledge. As part of a multi-case comparison, we looked backwards across multiple initiatives. Each initiative has its own organizing language, as well as its own approach to evaluation. Although this is one of the appealing characteristics of this form of comparison, reflexive comparisons require that one understands how deeply held each case is by each respective scholar. This risk exists in how researchers may avoid analytical inquiry into failure and the darker sides of transitions experiments and their evaluations (Caprotti & Cowley, 2017; Blythe et al., 2018; Collins, 2020). This bias could feed into the reflections that we share through comparison.

In this study, we have assumed that each evaluation logic, and lab process, has been designed with the interest of being self-critical towards one's own methodology. This decision was made given a shared interest and care in each other's work, as well as the care that we had for our own designs. Second, this study explores evaluations through a process of looking backwards, in the present, to learn for the future. Although comparisons on evaluation practices are important in opening up diversity in this space, it is also important to emphasize that focusing on evaluation comes at the expense of bracketing out case-based insights for each lab. By saying more about three cases in relation to eachother, we say less about each specific case. For each case in paper IV, empirical and conceptual inquiries are either ongoing, or have already taken place (cf. Williams 2019; Douglas et al. 2021; Slater & Robinson 2020).

		Research phase one To establish normative understanding of labs in real-world contexts	Research phase two To investigate learning within an educational sustainability-oriented lab	Research phase three To conceptualize and compare role of evaluation in sustainability-oriented labs
Research design	Adaptations	Initial aim of review was tightly bound, focused on development of analytical framework oriented around SDGS. This was discarded in favour of a more exploratory review	Adaption of course online due to COVID Co-production of research led to evolving RQ	Methodological movement from (1) broader theoretical entry point of evaluating futures not yet known, towards (2) reflexively understanding evaluative practice in experiments
	Opportunities	Intentionally exploratory framing encouraged a creative research approach and increased diversity of findings Broad search-string allowed for diversity in cases that would have not been possible if confined to specific discipline	By beginning with lived practice and experience in C-Lab learning environment, it became possible to explore dilemma as both practical and theoretical Supported exchange between insights and ongoing teaching. Rather than "data collected", reflections matured over time, with support from theory, and fed back into teaching Language of frames provides a basis for better understanding how we collectively shape learning spaces	Opportunity to illuminate the "how" of transformative evaluation. Enabled descriptive and reflexive accounts of practices of evaluating distinctly different evaluations alongside those responsible for design
	Challenges	Decision to keep review broad in the beginning. This resulted in fuzziness in terms of scoping	Empirically bounding case from other aspects of C-Lab. C-Lab as method, C-Lab as course, C-Lab as broader approach	
Research process	Opportunities	Moving beyond descriptive sample led to novel results, including: (1) identification of various discourse groups and labs of labs, (2) construction of labs as space, process and organization and (3) typologization of labs according to practices		

	Challenges	Time and commitment required for research design of this kind – iterative, systematic, reflexive Interpersonal challenges associated with ID research group Although broader than discipline, review suffered from overemphasis on labs that are defined as such, as well as those are published in this way. Remains unclear whether possible to transgress ideas of labs as research objects.	Interpersonal challenges associated with ID research group Numerous challenges associated with COVID-19 Pandemic – affective impact of education and living through crisis, time spent online, challenges with embodied learning	Limited feedback from evaluation back to processes – sense of "what could have been done differently" Challenge in searching for resonance across distinctly different initiatives Risk that methodology over-emphasizes the transformative appeal of cases. *Would this research design have created conditions for the meaningful sharing of failure* beyond pragmatic constraints (time and resource constraints)
Research results	**Generated knowledge and action for sustainability transitions**	Collection of 53 labs from review Overview of dominant conceptualizations of the lab Outline of labs as space-process-organization Sustainability as a dynamic property Empirically-grounded typology consisting of 6 different types – including Educate and Engage (Research phase two)	Conceptual delineation of challenge framing, in contrast with problem and solution-orientation Exploration of learning environments as a combination of intention, enaction and experience Reflexive discussion of dilemmas present in the space, shared through both designer and student experience	Three challenges associated with evaluation: (1) partial nature, (2) limiting the 'who', (3) lacking systems impacts Suggestion of empowerment, learning-oriented and systemic evaluation approaches Comparative account of three experimental forms of evaluation
	Limitation of results	Empirical limitations Risk of decontextualization Rendering static that which is fluid	Limited reflexivity regarding dilemmas as emplaced in course design can romanticize account Sense of over-emphasis on practice over theory – overdependence on the "doing" of the course, not necessarily "knowing"	Case divergence Focus on evaluation obscures other aspects of lab, such as design, politics of space, process Inability to evaluate way forward – advantages of anticipation, but room for uncertainty of sustainable futures

Table 6: Reflective account of research in this thesis, based on design, process, and results

11 Contributions of this thesis

As introduced in chapter 1, the aim of this thesis has been to *investigate how labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformations.* In approaching this aim, I begin by summarizing each research question, before distilling insights and contributions from this thesis by reading through and across each study.

11.1 Summary of research questions

RQ1: How might sustainability-oriented labs in real-world contexts be understood?

Paper I outlines that sustainability-oriented labs in real-world contexts can be understood as a collection of research-practice hybrids that are organized around sustainability issues. Their thematic interests range from urban and built environment, to education, food and water. These labs draw from a series of different theoretical roots, such as learning sciences, complexity science, participatory and user design, TD, urban studies, transitions and transformations studies. Although distributed across multiple countries, they have been influenced by prevailing European living lab and urban living lab traditions. This sample highlighted a series of theoretically rigorous and methodologically grounded lab approaches that have been based in Mexico (T-Labs), Vietnam (Evolutionary learning labs) and Zimbabwe (Change Laboratories). Labs bring with them plural funding models, some of which are long-term, as well as various forms of participation. In summary, sustainability-oriented labs can be understood as *spaces, processes and ways of organizing* around complex sustainability challenges, where sustainability is viewed as a dynamic normative property.

RQ2: As an educational lab, how does Challenge Lab (C-Lab) organize around sustainability challenges, and how do such challenges unfold?

Paper II explores a C-Lab curriculum from the perspective of challenge framing. As part of calls for education *in*, *for* and *with* sustainability, C-Lab is organized with the view that framing processes accompany complex challenges, as essential learning objects in educational settings. In exploring C-Lab as a curriculum that is intended, enacted and experienced, we investigate how complex sustainability challenges are framed in the learning environment. Here, framing processes unfold within C-Lab over time, creating different learning opportunities for all co-learners. For students, this experience shapes how they see their role within existing challenges,

how they navigate limits to knowledge in complex systems, and how they self-assess their own sense of comfort and progress as they navigate curriculum. This study also highlights how we as designers and educators navigate these challenges alongside students, as co-learners, in a manner that attempts to reciprocate uncertainty. This navigation emerged through three central dilemmas that occur in C-Lab: (1) the ongoing emotional responses that unfold within this learning environment, as identities and senses of progress are questioned, (2) the continuous tension between scaffolding for agency, learning or progress, and (3) the need to respond to strong historical expectations from students that teachers define curriculum and drive content.

RQ3: In which ways do sustainability-oriented labs engage with sustainability, and how can they be categorized?

Paper III builds upon the findings of paper I where sustainability was viewed as a dynamic property. In categorizing labs according to their engagement with sustainability, sustainability-oriented labs in real-world contexts can be grouped into six types: (1) *Fix and control*, (2) *(Re-) Design and optimize*, (3) *Make and relate*, (4) *Educate and engage*, (5) *Empower and govern* and (6) *Explore and shape*. In terms of engagement with sustainability, *Fix and control* labs view sustainability as a technical challenge and pursue efficiency adjustments*; (Re-)Design and optimize* labs are oriented towards consumption issues and lifestyle measures; *Make and relate* labs organize around the cultural forms of participation such as making, with an explicitly local focus; *Educate and engage* labs are experimental educational spaces that seek to rethink the relations between university and society through their pedagogies; *Empower and govern* labs approach interconnected urban issues with a governance focus; *Explore and shape* labs consider sustainability a complex, contested challenge, where its definition is subject to local contexts and situations. This typology illustrates a plurality of labs according to the objects of sustainability in focus, their overall orientations, as well as their core properties.

RQ4: What is the capacity of evaluation practices as a tool for sustainability-oriented labs?

Paper IV explores the capacity of experimental forms of evaluation that accompany labs and transition experiments. It is argued that experimental forms of evaluation have the potential to respond to three common pitfalls in evaluative practice. First, experimental evaluative practice has the potential to respond to the problem of *partial evaluation,* where explicit learning orientations can support in understanding both labs and their evaluations as dynamic processes in open systems. Second, empowerment forms of evaluation bring with them promise in expanding the remit of not only *who evaluation is for*, but larger questions regarding *for whom*

evaluation should serve. In this way, empowerment processes in evaluation are intended not to resolve issues of power in collaborative processes such as labs. Rather, they encourage an opening rather than a closure of these dimensions. Third, systemically focused evaluative frameworks attempt to engage with the challenges of *project-based evaluations that prioritise program over system*. Such an evaluation can serve as a strategic tool for intervention designers and participants to better understand (and communicate) how labs and experiments may contribute to broader transitions. In combination, the case reflections presented in paper IV are intended to encourage the development of evaluative practices that are suited to the experimental nature of labs, as well as the uncertain nature of sustainable futures. At the same time, they highlight that challenges are not specific to each case, nor are they easily overcome in practice.

11.2 Contributions from this thesis

The research within this thesis can be understood as *qualitative-dominant, case-focused, action-oriented and concerned with transitions and transformations.* In such a field, there is a natural inclination to pluralize quality and impact (Sovacool et al., 2018). This thesis therefore speaks to *multiple* conceptions of quality: its *qualitative nature* emphasizes thick description and credibility (Tracy, 2010); its action-orientation questions reflexivity, criticality and purpose; its case-*based nature* foregrounds generalizability and ethics (Stakes, 1995); with its location in transformations and transitions, there is *systemic intent* and an ambition to enhance capacities to act (Hölscher et al. 2021).

11.2.1 Practical-experiential contributions

This thesis contributes with practical-experiential knowledge regarding sustainability-oriented labs in real-world contexts. It has done this by:

Positioning labs as spaces, processes and ways of organizing around complex sustainability challenges (RQ1, Paper I).

This finding is a practically significant contribution in at least two ways. First, this distinction has been used as a way of approaching sustainability-oriented labs from a design perspective. Space-process-organization has fed into educational course designs within C-Lab (Holmberg & Holmén, 2022), as well as in approaching the governance of industrial transitions in North Middle Sweden (Douglas et al., 2021). In both contexts, this triad presents a way of framing C-Lab at early stages. Second, it has provided an aid to approach conversations of place-based experimentation in a learning-oriented manner, with an interest in searching for similarities and differences.

Developing a six-type typology regarding lab practices (RQ3, Paper III)

The empirically grounded typology, developed in paper III, functions as a way of distinguishing levels of sustainability as a broad matter of concern and as a locally emergent phenomenon. As such, it provides (1) a heuristic for situating and comparing labs as a rich set of transitions initiatives, and (2) a frame for reflexive lab design and praxis. Through the development of six types, it is possible to distinguish groups of labs that attempt to solve technical systems versus those that attempt to collectively approach coupled systems. In addition, it is possible to identify those who assign instrumental *(Fix and control)* or fundamental value *(Make and relate)* to participation; that create methodological space for engaging with values, systems, and

futures *(Explore and shape);* and that support the role of framing and reframing in understanding challenges in contexts *(Explore and shape).* It suggests a spectrum between incremental, solutions-oriented labs versus those which are oriented towards challenges in contexts.

This typology may support the informed choice of specific lab designs according to present interests and opportunities of engaging with sustainability, not by providing blueprints, but by indicating the broad options available. Our findings highlight how labs might share a commitment to sustainability discursively, yet in practice can contrast vastly in their entry points, understandings of sustainability, processes, and the nature of their collaboration. This typology and its associated dimensions therefore provide a frame for reflexive lab design and praxis, but it in no way attempts to simplify the complex nature of systems change. It maintains a focus on labs that express an explicit engagement with sustainability, claimed to align with the broad normative character of transitions towards sustainability.

Interestingly, the distinctions raised above resonate with transitions and transformations discussions that attempt to further articulate how labs impact change. They relate to the means versus outcomes of sustainability transitions as well as how transition processes may be inclined towards incrementalism or radical change (Meadowcroft, 2011). As echoed by Feola (2015), the integration of actors is not guaranteed by simply achieving diversity. Nor does it ensure that fundamental, or even realizable change will unfold as a result of the decisions made. Reed (2008) attributes this contradiction to the tensions and trade-offs between participation as a democratic right that enriches decision-making processes and outcomes, and the connection of participatory practices to existing economic, political, and environmental logics.

Investigating how learning environments grapple with complex sustainability challenges (RQ2, Paper II)

As highlighted in Chapters 6.2.3 and 8.2, the investigation of framing in C-Lab involved continuous movements between practice-theory-practice. In learning more about how the framing of complex sustainability challenges unfold in educational curricula, the ambition of paper II was to improve framing practices within C-Lab. As a form of educational research, its interest was in *"informing educational judgements and decisions in order to improve educational action"* (Bassey, 1999, p. 39). Therefore, an important question becomes: *are we better equipped when framing complex sustainability challenges?*

Since this investigation in 2020, praxis around framing have provided a language when designing for each year; in addition, designers have a basis for exploring dilemmas with students as internal to the learning environment. Adopting a complexity perspective, this

means recognizing an inability to avoid contradiction, but rather to see it as an entry point into deeper layers of reality (Morin, 2008). In addition, it provides a basis for the negotiation of values and expectations during challenge-driven approaches to sustainability. For example, it becomes possible for us to draw from experiential knowledge regarding conversations of progress, ownership and uncertainty, as well as to become more open and transparent around when we may feel that we move in divergent directions during a course. Regarding challenge-driven learning environments, it provides a layered account of how challenges unfold in C-Lab, whereby such challenges must be framed and created as part of learning one's way forward (Engeström, 1987).

11.2.2 Empirical-conceptual contributions

This thesis contributes with empirical-conceptual knowledge regarding sustainability-oriented labs in real-world contexts. It does this by:

Highlighting the rich landscape within which sustainability-oriented labs currently exist (RQ1 & 3, Papers I & III)

In papers I and III, I integrate knowledge on sustainability-oriented labs from various areas of application, research communities and cases. Papers I and III generate a cross-field understanding of 53 different labs, from seven different research communities, that have an orientation towards sustainability. This approach is novel in that it not only supplements existing collections of labs that often focus on a specific concept, field of research or thematic area; it provides a more directed focus on those that explicitly relate to sustainability in a normative manner at the level of intent. Rather than focusing on lab approaches that treat sustainability as secondary to their activities (as is the case in oversight reviews such as Hossain, et al., 2019) we treat sustainability as a bridging concept, capable of generating complementary and integrative insights. We held an interest in generating knowledge that can allow for conversations both between research and practice, as well as across fields concerned with sustainability transitions and transformations.

Nuancing the conversation around sustainability in labs (RQ1 – 3, Papers I – III)

Despite a view that these labs share a commitment towards sustainability, we were interested in how these commitments are embedded differently into the design and ambitions of labs. Paper I presents labs as a combination of *space, process and way of organising*, a characterization of lab practices specific to those oriented around sustainability. In addition, we establish sustainability as a *dynamic normative property* in labs, a property that that is broadly

shared across all cases yet interpreted and practiced in different ways in each context. This finding established the basis for a deeper comparative approach, knowing that there was a need to openly question the goal-based nature of these initiatives given their different designs, conceptualizations, and contexts. Paper III extends the comparative strength of this thesis through the development of six empirically grounded lab types. Each type expresses different relations between broad sustainability topics, as well as more contextual ambitions that represent sustainability in place. Paper II introduces the notions of complex sustainability challenges as a gravitating element that unfolds within labs. This conceptualization can be understood as an extension of the view that sustainability is a dynamic property of labs. It is paradigmatic, moving beyond problems and solutions in society. In addition, it distinguishes challenges framing from problem-based learning environments that are either idea-driven or focused on pre-defined tasks and projects. The introduction of challenges as subject to framing processes highlights the importance of recognizing complexity as an ontological feature, whereby organizing around problems provide entry points into their shaping. Importantly, the combination of challenge framing as a learning orientation and C-Lab as a learning space, creates a frame for overcoming dead-end solutionism as learning processes unfold.

This thesis combines existing theoretical and conceptual frameworks to better contribute knowledge on labs. It does this by:

Generating oversight of theoretical viewpoints held by sustainability-oriented labs (RQ1, Paper I)

Rather than limiting to specific fields of discipline or conceptualizations – a common methodological choice made in other studies of relevance (Hossain et al., 2019; Schäpke et al., 2018) – the research within this thesis identifies and unpacks labs with an interest in practical and theoretical diversity. These labs can be located both inside and outside of the sustainability transitions community, bringing established concepts (living labs) into contact with alternative and burgeoning approaches (transformation labs). Points of overlap can be seen by some as a source of tension, where competing views may meet, and conflation occurs. On the contrary, I view this as a space where paradigmatic differences can be discerned, allowing those involved in understanding, designing or critically investigating labs to better explore the assumptions held within an approach. Additionally, I view this space as a source of comparison, collaboration, dialogue and ultimately, learning. As established in paper III, the recombination of practices that share a commitment to sustainability offers promise as a pluralistic approach to normative change in theory and in practice. These initiatives represent the seeds of change for place-based experimentation, committed to learning during transitions and transformations amidst uncertainty (Bennett et al., 2016).

11.2.3 Methodological contributions

In this thesis, I contribute methodologically to a growing set of lab approaches. I do this by:

Contributing to the methodological development of qualitative-interpretive systematic review processes (RQ1 & 3, Papers I & III)

This thesis presents a methodological attempt to conduct a systematic review process in an exploratory fashion. In research phase one, research questions served as a provisional anchor for data collection (Dixon-Woods et al., 2006). Papers I and III directed attention to reflect upon the methodological choices made, reflexive process for ensuring rigor, as well and their limitations. This is a deliberate choice made, to make visible the practices of engaging in review processes that are open-ended in scope. By doing so, my ambition is to reflect the ideals of sincerity, transparency and credibility that are claimed be of importance for qualitatively-oriented research (Tracy, 2010).

This thesis contributes to more recent studies in this field that have attempted to advance transition knowledge through a systematic review process. These include topics ranging from experimentation in both transitions and climate governance, actors and agency, and geographies (Fischer & Newig, 2016; Hansen & Coenen, 2015; Kivimaa et al., 2017, 2018; Sengers et al., 2016). What is noticeable about each review is that they often blend qualitative and quantitative methods for the collection and analysis of different phenomena. However, they tend to do so from within pre-existing labs (such as real-world labs – Schäpke et al., 2018), or with a particular analytical level of focus (such as that of discourse or policy – Sengers et al., 2016; Kivimaa et al., 2017). The methodological design in papers I and III are unique in that they combine (1) an interest in systematic data collection, (2) rich sample descriptions, (3) a discourse understanding of research traditions, 4) a provisional development of labs as spaces, process and ways of organizing, (5) a 2-tier conceptualization of sustainability as generic and situated, as well as (6) an empirical classification of initiatives in the form of a typology.

Combining single and multi-case strategies for complementary comparative insights on labs (RQ 1-4, PI-IV)

The research strategy contained in thesis explores labs from afar, alongside others and in the thick of it. This unique combination of single, collective and multi-case comparisons provides a rich basis to learn about labs in both general and specific ways. Generally, it became possible to better understand broad organizing dimensions, as well as grounding discourses. This form of research, systematic reviews, however, routinely struggles with a lack of thicker data. Ironically, it highlighted that theory-practice interplays are central to labs, without being able to unravel

what this might mean in a particular setting. By engaging extensively with C-Lab for five years, I was able to learn about how embedded forms of research and practice may function, where relations and thick empirics constitute the case.

Qualitative casework in the context of education, such as that conducted in Paper II, rests upon focusing on the specificity of case, as well as by combining theory and practice through reflexive methods. This form of casework reaches for resonance with others in an attempt not to say what should be done, but rather with a humble attitude that such spaces can benefit from exchanges with others (Danermark et al., 2005). The collective case comparison approach in Paper IV aims to offer a mid-range approach in comparative methods. In the process, it provides comparative knowledge regarding three challenges associated with evaluations (RQ 4, Paper IV). It has achieved this via (1) a comparative account of three experimental forms of evaluation, (2) the creation of space for dialogue to unfold, and (3) points of interconnection across cases to learn about what we have done. By engaging with cases at different scales, it could be argued that little can be said regarding how each transition experiment relates to eachother. However, the mutual interest in exchanging on evaluation as relational practice, as well as the intrinsic nature of each case, provides the conditions necessary for trying to learn together through case.

11.2.4 Reflexivity and positionality contributions

Reflexivity can have various meanings when thinking about research. In sustainability transitions and transformations, its centrality lies with enriching collaborative processes (Wittmayer & Schäpke, 2014). In praxis, reflexivity bends designs, processes and outcomes back onto itself to search for unintended consequences (Archer, 2010). The forms of learning generated by reflexive approaches span implicit assumptions, normative values, methodological movements, critical junctures, central limitations and evolving research processes (Fazey et al. 2018; Ness & Wahl, 2022). Reflexivity is particularly useful in normative approaches as it upturns assumptions and makes them visible to modestly interrogate claims to knowledge.

Reflexivity is central in co-produced research, where framings often influence the direction of research agendas. In addition, emergent knowledge and experiences support in iterating research designs along the way (Hölscher et al. 2021). With its reach of influence in arts and humanities, as well as ethnographic research traditions and action-oriented approaches, reflexivity can be understood as: (1) a methodological device (van Mierlo & Beers, 2018), (2) a quality criteria (Tracy, 2010), (3) a skill and practice (Wittmayer and Schäpke, 2014), (4) a way of being in the world (Marshall, 1999), (5) a capacity (Archer, 2007), or (6) a relational phenomenon (Fam et al., 2020). As such, there are subtle differences between nurturing reflexivity and becoming reflexive (Etherington, 2004, Archer, 2010).

In this PhD, I contribute to emerging debates regarding reflexive transitions and transformations research. I do this in two primary ways. First, this thesis generates process knowledge related to the research designs when engaging with sustainability-oriented labs. In each research phase, the need to think through assumptions and consequences of our work was different. Research phase one required us to adjust the research object over time, to align our approaches to data collection and to develop creative analytical processes. In my role, I therefore encouraged reflection on research processes at crucial stages. Within each research phase, we have turned to reflexivity in learn iteratively along evolving research designs. As an emplaced form of educational research, phase two recognized the interconnectedness of research, education and practice. Research phase three began with an interest in different cases, assuming that although each evaluation practice has its respective roots, it was possible in cases speaking within and across. In this thesis, process-reflections speak to the unique concerns and trade-offs of each phase, to position my role in this work, and its implications, in a humble manner. Second, within this thesis was an ambition has been to balance not only what I have discovered across my doctoral journey, but also how I have discovered it. This is reflected in a thesis that attempts to respect the open-ended nature of a doctoral journey.

11.3 Future research avenues

Given the multi-part nature of this thesis and its work, future research points towards both practical/purposeful and analytical/conceptual lines of inquiry. These are associated with the broad aims and results from this thesis, as well as emergent research strands.

This thesis points towards *the collaborative and relational aspects that are central to sustainability-oriented labs*. Amidst broader calls to rapidly transform systems that integrate notions of justice and inclusion, there are ongoing tensions between the rates of change and the scales of participation implied. This thesis therefore encourages future research, at this intersection, that:

Considers the role that labs can play in times of increased urgency, by:

a. Exploring how co-learning can employ and engage with the future in the here-and-now
b. Balancing the tensions between urgency to act and capacity to act in context
c. Fostering and enhancing collective forms of agency for enacting change
d. Navigating the affective dimensions associated with urgency to act, as well as the meaningful tension between participatory praxis and the acceleration of everyday life.

This thesis points towards the *importance of sustainability challenges in the framing of learning environments that are challenge-driven*. It builds upon the view of sustainability challenges as gravitating elements in learning environments (Wals et al. 2015; Holmén et al. 2022; Ness, 2020). In further developing research that concerns challenge-driven forms of education, this thesis encourages future research that:

(Co-) Designs transdisciplinary educational spaces, with a particular attention to:

a. Co-framing of sustainability challenges within multi-stakeholder settings
b. Understanding and navigating the politics of processes, as an internal element to educational settings
c. Exploring the role of facilitation and process development in challenge-driven settings
d. Illuminating broader approaches to co-produce curriculum and educational spaces
e. Understanding the interplay between forms of experimentation and dominant forms of educations
f. Exploring how labs can be synchronised, harmonised and amplified over time and space
g. Investigating contradiction as a locus of expansion and transgression
h. Fostering intersubjective and relational capacities in education, moving from 'I' to 'we'
i. Linking inner and outer dimensions of change through educational praxis.

This thesis points towards *the growing attention to experimental forms of evaluation that can support in enhancing the capacities of labs and transitions experiments*. Through the comparison of alternative forms of experimentation, we have tried to open up that which may exist, with a particular focus on reflexive evaluative practice. Although a modest contribution, this thesis encourages future research that:

Explores the capacity of evaluation for labs and transition experiments, by:

a. Theoretically and conceptually engaging with the implications of evaluating experiments in light of futures that are not known
b. Comparing experimental approaches to evaluation, to expand the possibility of appropriate frames for sensing and aligning with transformations
c. Experimenting with evaluation that can support in threading connecting between labs that are local or translocal in nature
d. Expanding the possibility of creative, reflexive and participatory evaluative practices in line with experimental practice.

Part Five: Reflections and considerations

In **part five,** I critically consider this work by approaching the question **"given what has been done in this thesis, how, if at all, is it transgressive?" Chapter 12).** I reflect upon my undisciplinary doctoral process in **Chapter13**. I motivate my decision to pursue what has, in some ways, become a "one-tonne" PhD, openly exploring how staying on the ground might be both expansive and highly mobile **(Chapter14),** before concluding with some final words for the future.

12 Emergent insights from this thesis

I have been unsure about the form that this section should take, and whether one is necessary. As highlighted in the chapter 1, there were several motivations for beginning an exploration of sustainability-oriented labs. Topically, labs appear as a burgeoning object of inquiry, drawing from design traditions, urban studies, learning sciences and transitions and transformations. As part of a larger experimental turn in society, their driving force was often one of engaging with local, place-based issues. Personally, I had been engaging with lab design and practice for some time and felt as if there was a disjuncture between their aspirations, theoretical descriptions, and actual practices. I found myself interested in following a different path, with the hope of connecting to the more normative nature of this work.

At this stage, you might be expecting me to say something about the broader transformative potential of labs. I have been hesitant to do this for a two main reasons:

1. The intention of this thesis has been to expand the possibilities of *unpacking, designing* and *evaluating* labs in real-world contexts. To then move quickly towards specific cases, or to make strong statements regarding what should be, will likely come short. After all, the contextual differences surrounding place-based experiments and labs mean that making persuasive claims regarding what is to be done remain elusive. These differences include, but are not limited to, the enabling or constraining conditions of place (Collins, 2020; Torrens et al., 2019), the socio-spatial characteristics specific to a context (Hansen & Coenen, 2015) and the degree of value divergence and controversy associated with matters of concern (Roberts et al., 2018). In short, I am mindful of the limitations of this research, knowing that "*there is no single knowledge system, method, or approach that can spur the diversity of actions needed to transform across scales*"[40] (Vogel & O'Brien, 2022).
2. It would be naïve to arrive to a blanket conclusion that labs are the most appropriate forms of governance for the pursuit of transformative change. To do so would in fact underplay the exploratory results from paper I, as well as the nuance in practices that we believe an empirically grounded typology (paper III) can provide. It would also break from the ontological and epistemological foundations for this thesis. Moreover, it would

[40] Of relevance here may also be the white spots in transformations: *Risk 1:* Transformation Discourse Risks Shifting the Burden of Response onto Vulnerable Parties; *Risk 2:* Transformation Discourse May Be Used to Justify Business-As-Usual; *Risk 3:* Transformation Discourse Pays Insufficient Attention to Social Differentiation; *Risk 4:* Transformation Discourse Can Exclude the Possibility of Non-Transformation or Resistance*; Risk 5:* Insufficient Treatment of Power and Politics Threatens the Legitimacy of Transformation Discourse (Blythe et al. 2018).

neglect the swelling interest in the hopeful questions of how to search for, support and meaningfully contribute to transformative change (Bentz et al., 2022; Fazey et al. 2018). To move forward with unconditional optimism would flatten the creative, plural participatory processes that intersect with labs in the real world[41].

Still, I am reminded of a few critical considerations that remain. *First*, by deciding not to make evaluative statements regarding the transformational potential of labs, it could be argued that this work falls into relativising. *Second*, given the diverse conceptual origins of labs, as well as the spectrum implied by six types, there may be more to say about intent, process or outcome. *Third*, there may well be other forms of labs and experiments that are not currently visible within this typology, as well as other scales of intervention that are important also. I find myself agreeing more with (2) and (3) than I do with (1).

12.1 The beginning - two distinctions

First, this work has sought to expand conversations, and to search for patterns of meaning that are not necessarily visible from within lab labels. Given that different lab practices move between theory and practice, some are more research-oriented or society-oriented than others. These movements are not necessarily better or worse, but they are different. More importantly, by recognizing this difference, it may become possible to learn from across labels in the development of improved practice. Related to (2) In developing a lab typology, I began to notice that many of the pitfalls of historical lab practices – of control, of closure, of objectification, of manipulation and of atomistic causality – seemed to appear in the descriptions and intents of certain labs within our samples.

The considerations above put words to some of the uneasiness that has accompanied me during this doctoral journey. In the first few years, I found myself searching for distinctions that could help in determining the role of labs in transitions and transformations change. This was partly fuelled by requests for methods and tools that can catalyze, as well as the growing interest in making evaluative claims regarding their impact. Although some types position labs **for** transitions and transformations, the governance of complex change requires labs **within** transitional and transformational change. *What does this mean, then, for the assumptions that have followed sustainability-oriented labs in transitions?*

[41] Recent work on amplification strategies (Lam et al., 2020), as well as those with a focus on transformative impacts are better suited to make claims regarding the future. The ongoing development of labs as part of systems that are not static but in motion, means that claims to the future must respect its non-linear form. In some ways, transformations are happening everywhere. In other ways, they are not easy to orchestrate.

Labs **for** *transitions and transformations* brings the connotation of labs as catalysing change framed their role as the starting point of a change process. This distinction at the same time embodied some of the more positivist notions of labs, however. Here, the language of control, of bounding and of monitoring impact, had made its way into labs in the real world. Labs were viewed as "injected", "implemented" or "implanted", creating a way of thinking about their role that seems to bracket context. This bracketing of context serves to develop experimental strategies that can be rolled out as pilots in cities and districts. Not only are these labs seemingly the closest to traditional counterparts, their infrastructures and funding strategies are the most robust. Funding spanned from 5 to 10 years, and in some cases even longer. This first distinction began to appear as lab types were developed in paper III, aligning with *Fix and control* and *(Re-)Design and optimize* lab types. *Fix and control* labs mobilize extensive infrastructures and resources around pre-determined issues, to be eventually "solved" via technological implementation. In other words, there were clear examples of sustainability being motivated to weave testbeds, smart platforms and experimental facilities into the urban fabric. There is a logic to experimentation that remains centred on control and intervention, extended beyond the confines of the traditional laboratory.

Labs **within** *transitions and transformations* present labs as part of a broader "logic of experimentation". It recognizes the relation between lab processes, parallel projects, ongoing stakeholder collaborations and dominant structures. This distinction suggests that spaces are made and re-made, existing between others forms of social activities. Labs *within* transformation recognize the ongoing and everyday nature of experimentation, as well as the possibility that they are resultant of systems change. For example, from the collective realization that new forms of organization are required. Here, the construction of the lab may be "emergent", "reinforcing" or "converging". With a more relational and situated understanding, the boundaries between internal and external are fuzzier and more overlapping. Complexity increases through the thickening relations between lab and context. This distinction was most aligned with *Educate and engage*, *Empower and govern* and *Explore and share* lab types.

12.2 An unfolding - zooming out

Over time, it became evident that although types in paper III provide a way of understanding a broad sample of labs, the directions they imply are not equal. *Fix and Control* labs bring the clearest associations towards closed, implementation processes. In addition, they overlap significantly with growing concerns around smart cities agendas that leverage technology from within a neoliberal urban agenda. Rather than collective capacities and complex beings, their intents are more of smart cities and passive citizens. In addition, the glaring absence of human-

nature relations means that questions need to be asked about their relevance in times of crisis and change. *Educate and Engage, Empower and Govern, and Explore and Shape*, on the other hand, resonate most with the experimental ambitions from within the transitions and transformations communities. They imply directional behaviour and presence through process in a manner that is diametrically opposed to implementation labs.

Which brings me to (3). Given that learning amidst uncertainty implies learning what is not yet there, it stands to reason that typologies freeze emergence. This may be partly true, an unfortunate side-effect of a review process. At the same time, the typology does point towards types that design with the expectation that emergence might occur. For example, within Xochimilco T-Lab is an expectation of movements in individual senses of agency, as well as a movement from individual to collective agency. This is built into process, without specifying the trajectories through which such movements may occur. From a learning perspective, labs such as Xochimilco T-Lab, and C-Lab (paper 2) for that matter, attempt to craft spaces where expansive possibility is latent but unarticulated. Not only do these labs *(not excluding educate and engage, and empower and govern*) provide the most apparent indications of reflexive and directional behaviour, they trigger me as the most profound for the times. That is not to say that there is nothing to be learned from living labs, urban living lab labels, or (re-)design and optimize types. Rather, it implies that contained within *explore and shape*, *educate and engage and empower and govern* is a possibility space that can broadly approach complex sustainability challenges. In my work, they provide a reference point that suggests a way of being in change. This base can then be complemented with co-creation techniques from living labs.

By beginning beyond types and within context, I find myself needing to let go, at least provisionally, of the work that I have also done, in order move forward.

12.3 A re-entry - Intervention or invitation?

As I reflect on these distinctions, as well as how they have accompanied this journey, I am reminded of the following question: *"How is this work transgressive?"* (Lotz-Sisitka et al., 2016). *How are we upending, challenging and questioning the assumptions, the dualisms, the anthropocentrism and objectification of traditional academic knowledge?"* (Temper et al., 2019, p. 12). With these questions, I find myself wondering about deeper, foundational assumptions that support sustainability-oriented labs in the real-world.

What might it mean then if we shed the language of interventionism for a moment? Let's try to shake things a bit, then.

12.3.1 The intervention

As highlighted in chapter 3, the phenomenon of labs mixes interventionist references from natural sciences (experimentation, control, bounded, testing) with concepts that indicate integrative work between multiple actors (co-production, co-creation). In this thesis, the term intervention can be seen as a boundary object. Within more classical sciences, interventions are located at the level of experimental method and associated with observation. It signals a movement made by a subject on an object, a form of stepping into the natural order of things through the manipulation of a certain series of events. In educational sciences, interventions resonate with the practice of adjusting education at the level of measure, in search of effect. It ranges from the notion of intervening as an educator from the outside, to interventions as collective responses within educational settings (Danermark et al. 2005). Evidence-driven approaches to education may for example focus on educational interventions that seek improvement in educational quality through an interest in the most effective intervention (Bassey, 1999). Within systems thinking Meadows (2008) refers to places to intervene within a system, and Midgely (2000) refers to interventionism as a purposeful action by an agent to create change. At the same time, Meadows highlights that modern approaches to complex challenges are plagued by an addiction to interventionism. Interventionism, when linked to the first distinction above, embodies several assumptions that are problematic in the context of complex challenges. As summarized by Marchal et al. (2013):

> *This view ignores other elements of complexity, such as [a] the principle of non-linearity (i.e. that a small change in input may, under certain conditions but not others, produce a large change in outcome); [b] the key contribution of local adaptiveness and feedback loops; [c] the phenomenon of emergence; [d] the importance of path dependence (i.e. that a particular context has arisen for complex historical reasons and interventions need to take account of the path of history rather than view current reality as a 'freeze frame'); and [e] the role of human agency (that complex interventions are introduced, delivered and at times resisted by people who have identities, values, skills, beliefs, goals and so on)*
>
> *p. 125*

12.3.2 An invitation

> *The world is not readily knowable. People who were previously dismissed as below notice, even if "respected" in the purely formal sense, might turn out to be quite fantastic companions, lovers, adversaries, or who knows what, if*

> *offered the "space," the invitation. Or perhaps they would choose to have nothing to do with us—a state of affairs from which we could also learn. We must ask them, however: we must venture something, expose ourselves too; and for any number of reasons the invitation may be declined.*
>
> *Weston and Cheney, 1999, p. 68*

> *To "invite," then, is not merely to make a space for something, to let it in: it is, literally, bringing new possibilities to life. Without it, without venturing real-world invitations, we cannot begin to know what the real possibilities are.*
>
> *Weston & Cheney, 1999, p. 77*

Transitions and Transformations towards sustainability require that we acknowledge the instability and open-endedness of the social, as well as presence of multiple scales of change over time. In advocating for actionable knowledge, with a view that systems are open, serious questions can therefore be asked regarding the ethics of labs. The work of Weston & Cheney (1999) helps further in getting the heart of the matter. They propose an ethics-based epistemology underpinned by three guiding assumptions: (1) *ethical action is first and foremost an attempt to open up possibilities, to enrich the world*, (2) *hidden possibilities surround us at all times*, and (3) *ethics is pluralistic, dissonant, discontinuous—not incremental and extensionist.* By inverting the logics of old, an essential characteristic of sustainability-oriented labs might then be one of reconnection. According to Weston and Cheney, a mode of reconnection is, rather than intervention, an *invitation:*

> *When we bear witness and listen otherwise, we listen from a space of unknowing, loss of control, loss of ideas and concepts; an opening to what is, not shrinking away, being there. And it is from this place that the ethical response emerges. Bearing witness gives rise to a listening without resorting to what is easy, what I already know, or what we have in common. It means that I listen for and make space for the difficult, the different, and the radically strange. I turn toward rather than away…*
>
> *Lipari, 2015, p. 187*

Ethics-based epistemologies are relevant in that they imply that how we act, and how we consider ourselves in relation to others around us, has fundamental implications for how capacities to act are conceived. They require care, but *care* that is antithetical to systematic

carefulness centered on control. This shift echoes what Moriggi[42] (2022) refers to as research that is *care-full.* It implies a fundamentally different way of engaging with the world. The creation of space is therefore built upon ethics: from a care perspective, it is *ethics-informed*, where multiple participants shape the conditions for responses that can co-evolve or emerge over time (Moriggi et al., 2020). Labs as invitations recognizes the experimental, open-ended, and highly personal nature of its working. Moreover, given the ambition to co-create, relationships lie at the heart of what they do. *What possibilities might arise through a re-entry into labs, not as intervention but invitation*?

Inviting from within systems

> *Our task is not* **to "observe"** *at all—that again is a legacy of the vision of ethics as belief-centered—but rather* **to participate**.
>
> *Weston & Cheney, 1999, p. 79.*

> *Systems can't be* **controlled**, *but they can be* **designed** *and* **redesigned**. *We can't surge forward with certainty into a world of no surprises, but we can* **expect surprises** *and learn from them and even profit from them. We can't* **impose our will** *on a system. We can* **listen** *to what* **the system tells us**, *and discover how its properties and our values can work together to* **bring forth** *something much better than could ever be produced by our will alone.*
>
> *Meadows, 2008, p. 169*

In the vein of invitation, the importance of nurturing a disposition towards both complex systems, as well as selves in systems, cannot be understated. Ontologically, systems inquiry de-centres systems "out there", inflecting towards the task of living within complex systems over time. It signifies what it means to be in a world where unsustainability is a symptom of systems that we are nested within. Epistemologically then, in light of the undetermined nature of reality as well as our embeddedness within complexity, a meaningful question might be: *how can we organize systemically to learn forward and seek meaningful change?*

Leverage points thinking stands as an example of the potential of invitation. Meadows (2008) referred to leverage points as "*places within a complex system (a corporation, an economy, a living body, a city, an ecosystem) where a small shift in one thing can produce big changes in*

[42] Moriggi et al. (2020) articulates a form of transformative research from a care ethics perspective. Caring transformations research builds on three dimensions: (1) ethically informed practices, (2) relational responsibility and (3) emotional awareness.

everything" (Meadows, 2008). Sounds profound, right? However, as highlighted by Meadows, in conceiving of leverage within systems, its metaphor it is one rooted in panacea:

> *This idea of leverage points is not unique to systems analysis—it's embedded in legend: the silver bullet; the trimtab; the miracle cure; the secret passage; the magic password; the single hero who turns the tide of history; the nearly effortless way to cut through or leap over huge obstacles. We not only want to believe that there are leverage points, we want to know where they are and how to get our hands on them. Leverage points are points of power.*
>
> *p. 146*

As introduced in section 4.3, panacea thinking has proven pervasive in approaching complex sustainability challenges. It tends, more often than not, to favour simple problems, framed via reductionism and resolved via techno-managerial solutions. Therefore, panacea thinking shapes what, how, and who, of change in a situation. From a complexity perspective, panacea thinking necessitates a rapid linear movement between problem-solution and cause-effect chains. In other words, leverage points carry a strong interventionist logic, a particular frame, that has proven remarkably hard to shake. Although Meadows starts the debate around leverage points thinking as a systemic concept, she stops short of confronting the assumption around control. Leverage points sound too good to be true, partly as they are just that. Given the failure of reductionism to provide entrance to complex issues, what might it mean to approach systems by virtue of invitation?

As invitation, then, leverage points thinking highlights the latent potential held within purposeful action, as one of exploration. Over time, its meaning has diluted from a *metaphor* for change, towards *rational points* in *hard systems*, to *bundles of points* within *constructed systems*, towards a *broader heuristic* for *inquiry* within *learning systems* that mediate between reality and experience (Abson et al., 2017; Woiwode et al., 2021; Davelaar, 2021). Although growing in sustainability science and transformation studies, researchers seem aware that leverage points continue to perpetuate a mechanistic view on change (Abson et al. 2017). Processes of setting boundaries together bring provisional systems *into being;* thinking about leverage emphasizes the ethical nature of action in context; critical reflections towards transformative potential focus on collective and individual capacities within intersecting systems. How we approach leverage as a metaphor – as a mechanistic point of intervention, or as a generative source of change that connected multiple systems – therefore implies an ethical disposition towards how we exist *alongside* change in an uncertain world. Meadows suggests that we use language *with care*, but as invitations the language *of care* might matter more. We see a glimpse of such a counter frame, its metaphorical implications in the making:

> *Magical leverage points are not easily accessible, even if we know where they are and which direction to push on them. There are no cheap tickets to mastery. You have to work hard at it, whether that means rigorously analyzing a system or rigorously* **casting off your own paradigms** *and throwing yourself into the* **humility of not-knowing.** *In the end, it seems that mastery* **has less to do with pushing leverage points** *than it does with* **strategically, profoundly, madly, letting go and dancing with the system.**
>
> *Meadows, 2008*

As explored through leverage points, considering systems thinking as an invitation presents an opportunity for complex challenges to emerge within context. *Inviting from within systems* highlights the need to approach change in a participatory fashion, as part of a search for individual and collective potential. It foregrounds the indeterminate nature of reality and the incompleteness of our knowledge of it. In addition, it highlights the importance of critically informed action as one which searches for openness and possibility within systems, and which distinguishes an action from other possibilities (Cilliers & Preiser, 2010). The ethical implications of such a practice are manifold. First, an invitation serves to recognize that complexity within systems signifies an admission that one must live with and through such complexity. Second, systems as invitation rejects the reduction of ethics to methods and tools. Systems inquiry advocates for an ethical sensibility that underpins the development of practice. As systems inquiry is highly experiential – that is to be practiced and not only theorized – it implies that the ways in which systems come to be constructed matters. Third, ethically-informed systems thinking collapses the illusory nature of observation and the fallacies of intervention, instead emphasizing the need to *participate* in constructing new systems.

Inviting for futures

> *The future can't be* ***predicted****, but it can be* ***envisioned*** *and* ***brought lovingly*** *into being.*
>
> *Meadows, 2008, p. 169.*

As established at the beginning of this thesis, navigating complex change towards sustainability requires novel modes of governance. It is becoming increasingly clear that as stakes are high and terrain uncertain, there is mounting pressure to induce, guide and accelerate systems change at a pace not previously experienced (Ehnert et al., 2018; Markard et al., 2020; Roberts et al., 2018). As established in paper III, establishing collective forms of direction adds additional complexity, where epistemic uncertainty can lead to stances that are at best anticipatory, and at worst elite capture. At the same time, transformative change is one of few constants in the

personal and political spheres of life (O'Brien, 2020; West et al. 2020); and ID, and TD approaches are relational pursuits that require social capital, time and energy (Sellberg et al, 2021). Transitions and transformations are first and foremost *felt* (Moriggi et al., 2020; Woiwode et al. 2021), and the stratified nature of the social world can differentiate capacity to act and collectively move forward (Archer, 1995).

Inviting for futures in transitions and transformations through lab processes therefore has implications for navigating change. Ontologically, it piques interest in the nature of the future as something that although we live through, exists as that which is 'not yet'. Epistemically, it raises questions of whether labs and experiments are heuristically prepared for engaging with the future in ways that are collective and creative, yet critical. This concerns the ways in which plurality and uncertainty can be articulated, comprehended, depicted, and codified. Methodologically, it concerns the performative and practice nature of futuring. Axiologically, it points to the normative views of the future as a political exercise. This includes who such categories belong to, how they come to be known, and how decisions regarding action can be navigated. It also casts attention to the politics of framing and negotiating the future, where actuality can emerge out of possibility. Returning to in-between nature, of labs Turner (1967) suggests that when working at the thresholds, we approach a *"realm of pure possibility whence novel configurations of ideas and relations may arise"* (p.67).

What if invitations are as much about reconnecting to the present, as constructing sustainable futures? As noted by Alhadeff-Jones (2017), conversations around the future are nested within the complexities of time. They suggest that, although transitions and transformations studies have become well equipped to investigate historical change processes, from within complexity arises the impossibility of control (Morin, 2008; West et al., 2020; Hebinck et al., 2022). As invitations that are underpinned by a view of ontological complexity, promising lines begin to open as temporalities become available. What might it mean for experimental spaces that create time? How might we think about slowing down and suspending time? How might we see co-creation as a process of multiple temporalities, including individual life histories, collective investments, planetary time, plural futures senses of stress and urgency? Inviting for the future within labs then emphasizes the importance of nurturing learning spaces where plural connections with pasts, presents and futures might be possible. These spaces can be considered as interconnected with the goal to pluralise the future by pluralising knowledge in the present (Nandy, 1996). Although its scale is at the level of course and curriculum, in the pursuit of learning for change it aligns with the view of Sayer (2011) that:

> *this is where we live – between the actual and the possible, between present flourishing or suffering and future possible flourishing or suffering. And because we live with others and have to act, we cannot evade ethical*

matters in our practice, even if we ignore them in what we read and write as social scientists.

p. 18

Inviting through education

Weston and Cheney (1999) point towards what higher education might look like if and ethics-based epistemologies are explicit in the educational mission. They suggest that it might mean that we nurture educational spaces that are based on trust and love. But in the context of higher education and complex sustainability challenges, what could this mean? This development is closer to what O'Donoghue (2014) refers to as the movement from interventionism in education to co-engaged action learning. Without being overly prescriptive, given than contexts differ and higher education masks diversity when approached in such a way, one could say that it could mean that (1) students and teachers approach educational situations *as co-learners*, with curiosity towards new forms of ownership (Carlson, 2019), (2) educational pedagogies attempt to *dissolve the separations between the university and the real-world,* (3) situations unfold as part of courses, meaning that the *negotiation of what is to be learned is internal to the learning environment*, (4) learning environments provide a space to reflect on the big questions that concern education, identity and integrity, promoting a connection between knowledge systems, multiple temporalities and everyday learning experiences.

Rather than viewing such an approach as devoid of direction, the above suggestions invite for emergent pedagogic approaches and learning spaces. Relatedly, they signal the inherently experimental nature of re-orienting educational institutions to attune to the call for transformation (Duraiappah et al., 2021; Rosenberg 2020; Lange et al., 2021). To invite for educational modes that are experimental, then, marks a movement away from the instrumental language of control and accountability upon which higher education routinely sits (Jickling & Wals, 2002). They must be thin, incomplete. These lines of re-orientation above also signal a grounded connection to challenges that are place-based and situated, a form of thinking and action *"that knows it is always local, situated in a given time and place"* (Morin, 2008, p. 98). They call for new ways of thinking about who education is for, how it can be approached meaningfully (Rosenberg et al., 2008), as well as how education practices can begin beyond an illusion of control (Morin, 2008, Facer, 2013).

Within such invitations therefore is that of possibility, to expand and enrich, setting new learning directions in motion, and this need not be negative. In our most recent C-Lab course, students expressed an interest in organizing around the topics of education and learning, providing an opportunity to link together their own learning histories with the desirable notion of a sustainable future on campus. This topic was not forced by us as designers but emerged across

multiple groups through the feeling that safe spaces, in combination with multiple relations to time, can trigger reflection on the problematics of their own education in the past. Such a re-orientation therefore concerns not only content, curriculum, or course. It concerns the task of approaching learning environments in a way that encourages possibility to form at the level of relation[43] (Abson et al., 2017; Engle, 2006).

[43] According to Greeno & Engeström (2006) "*expansive framing includes an expansive understanding of the object of learning, and an expanded understanding of learner agency that includes learners actively participating in the construction of their knowing and understanding of the subject matter.*" (p. 133)

My presentation at the ACT! Sustainable Conference, Act Sustainable: Researchers Roundtable for Sustainability, Gothenburg, Sweden, November 18th, 2021

What I will share with you, for 5 minutes, is a layered vision of how educational institutions might look if they *reorganize* in response to *complex sustainability challenges*. This vision contains, amongst other things, *normative claims made from within the field of action research*; my own *values and assumptions* around the possibility of research and social change; claims from *social and transformative learning for climate change* and *expansive pedagogy*; *collectively generated principles* during a master's course on leadership for sustainability transitions, completed in October 2021.

I would like you to imagine an institution that acts with *purpose* and *courage*. That does not respond to market needs but derives its moral compass from *pressing challenges of our time*. A university that places climate change *alongside* inequality, poverty, education, pollution, physical, mental, and planetary health. I would like you to imagine a university that is accountable to its *vibrant local community*, to its *friendly neighbours*, to its *hopeful children*, to its *collaborators*, to its *colleagues* and to those of us *without voice* or *representation* and to those who *inhabit this world after us*.

I would like you to imagine an educational institution where research is not done *on* people, but *with* people, *for* people. Within this university, *challenges* are in the centre, not solutions. Where our research questions are not *dreamt up in an office* or *found in a book*, but *emerge* from deep, reciprocity *with others*. Where *humility, power, relationality, care, values, trust, listening, ethics, uncertainty, history, experience, assumption, and boundaries* support the search for actionable knowledge.

I would like you to imagine that within this institution there are spaces where *co-learners* are encouraged to learn "*what is not yet there*". I would like you to imagine a curriculum where *leaders learn,* and where *learners lead*. This might mean that learning outcomes are socially shaped *together*. It might mean that *different expectations* form a necessary layer of a transformative learning environment. Where the boundaries of our own knowledge are not a sign of *weakness* or *stupidity* but are *boundaries of possibility* to work with others.

I would like you to imagine a learning space where the *future* is not seen as *singular*, *taken for granted* and rendered formality. Instead, *frames of the future* are placed in front of us, as *resources for learning*. That sees the future to be *shaped*, to be *envisioned*, to be *resisted* and to be *collectively created*. Where in the context of sustainability, *feasibility* is tempered by *choice* and *desirability*. Where *openness*, *novelty* and *hope* are woven into *direction*. Where *students* are seen not as *inhabitants of the future, governed by their past*, but *future makers* as part of a *"pedagogy of the present".*

I would like you to imagine a space where **systems** are chosen over parts, **relations** over disciplines, **agency** over obedience, **deliberation** over rational choice, where change out-there is linked with change-*in here*. Education, research, and action *dance together* and feed into eachother, rather than walking in single file. Where teachers, learners and students *learn together*. Where *care is cultivated*, rather than control exerted.

This is an open invitation to collectively consider the future of educational institutions, our roles as teachers, researchers and educators, and our capacity to act and actively shape new learning environments that might be necessary for transformative change.

12.4 Final words on the educational imperative in times of change

As higher education institutions, universities are embedded in the social fabric of modern society[44]. In conversations around climate change and pervasive social issues, such as the ongoing COVID-19 pandemic, there has been a rekindled expectation of sorts that our saviour is to be found in the classroom, behind a desk or in the lab. Things do not just happen *in* universities. They happen to a large extent *because of* universities. And yet, there is no viewpoint from which they can be understood as singular. Perhaps most importantly, from the discrepancy between progressive educational projects and the realities of higher education, there is a paradox. Awareness of unsustainability in public discourse continues to grow; universities are more widely populated than ever before, both by students and researchers. The goals of the higher educational mission – of instilling a moral and ethical compass, and building capacity to think, act and be in the world together (Freire, 1970; Facer, 2013; Barnett, 2004; Wals, 2015) – seem a perfect fit for times of transformation. Yet, where questions of sustainability are linked with, but not limited to, a rapidly warming planet, the university finds itself in a tricky position:

> *The people with the biggest ecological footprints are not the ones who received no formal education living in poverty but are the ones with PhDs, Masters and Bachelors degrees […] The conventional wisdom holds that all education is good, and the more of it one has, the better[…] The truth is that without significant precautions, [it] can equip people merely to be more effective vandals of the Earth.*
>
> *David Orr in Wals, 2015*

Reconnecting back to the aims of this thesis, and the studies within, I remain mindful of the temptation to overstretch regarding the big conversations that higher education is currently facing. After all, education represents but one thread in my research strategy. At the same time, because its significance has grown from within, alongside a strategy that has descended from the general to the specific, I feel a need to step back and search for meaning. The aim of this thesis has not been to investigate the bigger changes per se. *Educate and engage* labs, and C-Lab, are in some ways, more focused on a scale of change within universities. At the same time,

[44] The university exists as a site where flows of students, teachers, researchers, stakeholders move through in continuity. Historically, they belong to some of the largest and most persistent knowledge infrastructures around, with the university of Bologna dating back to the year 1088. Nowadays, universities are dynamically shaped by, and shape their surrounding streets, neighbourhoods, cities, and regions. The idea of the university is also cultural and symbolic. It endures in the collective imagination as a place to nurture the brightest, most diligent, and most 'successful' in society. Parents aspire for their children in search of better life opportunities and conditions, and adolescents search for meaning and collective purpose during university life.

labs in education could not be more relevant, suited for the big things. Because trickle-down approaches to educational reform routinely encourage incrementalism, a promising feature of labs lies with their disruptive capacity. They are in some ways prefigurative, preparing for change in the present that might precede transformations in the future (Boggs, 1977). If understood as a form of reflexive governance, within labs lies a latent potentiality to relate and link itself to the sets of complex feedback at a local level (Holmberg & Holmén, 2022). At the same time, understanding such settings as suspended between 'no longer' and 'not let' brings with it a space for untapped creativity and experimentation.

Experimentation in education does, however, carry its own vulnerabilities, particularly when faced with knowledge systems that resist change. For this reason, within each lab is a tale to be told of the scales and orderings of change that such experimental practices imply. As we experiment, our conditions may influence shift learning environments in different ways (Voss & Kemp, 2005; Amsler & Facer, 2017). Within research phase two, although our methodological approach and findings are located at the level of course and learning environment, some of the above dynamics around C-Lab have been felt throughout this thesis. For example, even though the importance of space, process and organization has been highlighted in phase one, C-Lab is as much a story of adaption as one of learning. Physically, the educational environment has changed three times since 2018. COVID-19, combined with Institutional decisions at the university level, shifted the conditions for the space to exist in its form. The emotional dimensions of C-Lab came into view, possibly as a mirror of both the deep uncertainties into the future and the immediate social consequences of COVID from local to the global. Processes have evolved alongside new inspiration, new co-learners in the lab as well as expanding research-practice agendas. As C-Lab has unfolded, the lives of those have continued in parallel. In addition, these interactions are contextual endeavours with their own flavour, reflecting the fact that universities carry regional, pragmatic and disciplinary identities. In C-Lab, the legacy of techno-centrism, engineering and positivism brings unique conditions to the learning environment. In addition to illustrating to how sustainability challenges can be grappled with in context, my hope for this section have been to situate C-Lab as existing *somewhere*. I highlight that the changing conditions for experimentation can (1) immediately impact such learning environments, (2) open-up or close-down the possibility of complementary forms of experimentation in the short and long-term (Torrens et al., 2019).

As I and others have experienced time over, then, labs are entangled within systems that are themselves subject to complex change. And, of course, change can, and arguably must, transpire from across systems. Dominant knowledge systems responsible for education, interrelated with academia, are in need of transformation also, raising deep questions of

relevance[45] (Facer, 2022; Moser & Fazey, 2021; Sterling & Orr, 2001; Akkerman et al., 20201). *Where might potential for such change lie, then?* Well, first, as others have argued it might include the *guiding values* that pattern the educational mission as one that can support transformations of the self, within systems, as part of natural and social worlds; (Wals, 2015; Lota-Sisitka et al. 2015; Chikamori et al., 2019). Second, it might concern the need for *reforms at the level of educational program* that can support in the re-orientation of education towards situated matters of concern at the level of course (Loorbach et al., 2017). Third, it might require the willingness to *approach sustainability as a multidimensional learning* object that links the local and global (Wals, 2015; Greeno & Engeström, 2006; Ness, 2020). Fourth, it might come from taking seriously the *embodied and affective dimensions of learning* implied by such transformations (Verlie, 2019). As highlighted above, higher education is often regarded as a site where the learning for transformation can be pursued. But what if, given that futures are uncertain, and fragmented knowledge seems unsuitable for the changes that we are both *experiencing*, and *seeking*, transformations must unfold through education. What if, rather than higher education as a catalyst for sustainability, sustainability poses a question of transformation to higher education? Beginning beyond this question brings into view the practices and pedagogies underlying community driven (Chatterton, 2000; Facer & Thomas, 2012), transgressive and co-creative (Lotz-Sisitka et al., 2015; Ishihara et al., 2021), and challenge-driven (Wals, 2015; Cox et al., 2021) educational orientations.

For those of you who find yourself identifying first and foremost as researcher, you might be wondering *"what has all this to do with me?".* After all, the student may seem very far from the world of research. Well, student learning experiences in higher education tends to be shaped by educators who largely identify first and foremost as researchers. Among the diverse linkages between education and research, there are educators who find themselves disenchanted by the daily demands of their work and the challenges of educational response (Berg & Seeber, 2018); researchers who find themselves squeezed between swelling commitments and shrinking time (Alhadeff-Jones, 2017); research divisions and faculties who find themselves swept up in the rush to publish and to secure funding within an increasingly projectified landscape.

[45] For example, the banking model limits how alternative educational responses can be thought of in the search for sustainable futures, the current realities of learning, and its governance into the past. Freire (2000) presents the banking model as a transmission approach to knowledge and learning, where students are framed as recipients of pre-determined knowledge. The role of the teacher is therefore to efficiently deposit this knowledge in the most efficient manner, *"education should make them more passive still, and adapt them to the world*" (p. 76). Banking education streamlines and flattens learning*; "a mechanistic, static, naturalistic, spatialized view of consciousness, it transforms students into receiving objects".*

As highlighted before, both research and education matter profoundly to eachother. The double-edged sword of the interplay between research and education is compounded by both educational institutions and academic institutions that are producing unsustainabilities from within. According to Akkerman et al. (2021) issues of relevance are hollowed out by both research and education to that of methodology, at a time that concerns relevance as deeply axiological, epistemic and ontological.

Returning closer to the scale my inquiry in C-Lab, I am reminded that as learning concerns becoming (Freire, 2000), possibilities of transformed praxis and collective agency lie between educators and students. In short, because education for sustainability is a task of not only epistemology, but also one of ontology, its relevance is derived from being in the world and changing it for the better with others (Barnett, 2004; Akkerman et al., 2021). For PhDs such as myself, first exposures to education leave an imprint on how we nurture educational praxis into the future. They transform our own experiences as students into our expectations as educators. Such movements, if radical or incremental, signpost what we expect of ourselves; what we think we and others bring to the table; what we prioritize within the act of teaching and the spaces we hold. Crucially, they shape whether we see this as an act at all, or just what "is". Educational exposure at early-career level, if not subject to continuous reflection, may only render most visible the things that we miss along the way, long after we have missed them. If to enter a discipline is to be disciplined (Sword, 2012), then our entrance into a classroom patterns how educational missions become available *within, through and from* us (Parker, 1998). *What if higher education is ultimately a matter of integrity and identity that requires nurturing?*

The insights from this thesis might remain a long way from specifying the transformations necessary for educating in times of change. In some ways, they echo the enormity of the task at hand. Yet, they also find hope in the potential of educators-as-researchers and researchers-as-educators in higher education. Through educational praxis, I shine light ongoing attempts to engage with challenges in place. With these final words, I specify not what should be done at the level of course and curriculum, knowing that *"from a realist perspective, knowledge does not become more 'practical' in this way; more likely it becomes of very little use in practice"* (Danermark et al. 2005, p. 189). Rather, my hope is for these accounts to resonate with those who are concerned with education of our time, committed to its betterment, and who are searching for, experimenting with, and adapting, spaces at the in-between. I claim not to solve a problem or close a conversation. Quite the opposite, really. I hope for openings that are unforeseeable, yet might become crucial.

13 Reflections from my doctoral journey

Travelling conversation during the course CEFO PhD Course: Leadership for sustainability transitions

May 12th, 2021

Gavin here. I have tried to sit and begin this letter on at least five times, unsure of where it may take me. I'll try again, and by beginning on a more positional note, I hope I can move forwards, or backwards, or sideways. I'm unsure what progress is in a round robin letter exchange!

I was initially curious about the first letters in this chain for these reasons, - this has become a rich and plural space, regardless of lecture content. I have been inspired by how you have all woven identity into your writings. I will try to do the same a bit here. With an undergraduate degree in Geography, my understanding of the world was of one of coupled interaction. Its ontological and epistemological premises are plural, spanning positivist, constructivist to postmodern traditions. My masters' was in within sustainability science, an international and interdisciplinary field focused on shared societal problems.

Yet, I identify neither as geographer, nor sustainability scientist. Rather, I belong to a generation of undisciplinary scholars whose journey is not bound strongly to disciplinary conventions. I share the view that transgressing and connecting across disciplines is key (Haider et al., 2018; Robinson, 2008). It is only until recently that I have been able to reconnect back with my ambitions to follow this path, ambitions that are not the product of indecision but appear to have been more and more purposeful as I reflect upon its development. I've grown to find scientific imperialism to be an authoritative influence, bounding the right to pursue and "produce" meaningful knowledge into the hands of very few people, at the expense of others. This development is inherently at odds with my conviction that science should be emancipatory. As I crossed disciplines, I realized that all of these are bound in some way, preserving claims to knowledge, and elevating the research above those around them.

I found myself drawn to Mikkel's use of "unlearning" here, when thinking about my discomfort with behaviour change. I wonder if behaviour change suffers from myopism. Is it helpful for me to be seen as behaviours, the sum of which constitute my lifestyle? Is there, or will there ever be a correspondence between the values that I espouse and those I enact? Am I more than behaviour? And is there essentially more – both to the self and the system – to the behaviours that I perform? After all, if we conceive of the systems around us to be of an open-ended nature, we must also believe ourselves to be intertwined within these systems in different ways.

I'm left with the feeling that I need more time, more space, more resources, more drafting, more clarity even in my own writing. Isak's letter feels so far from mine now, as I move farther down the page. I scroll back and forth as I try to reconnect with his experiences, trying to find spaces to weave in and relate to him through my own. But I also believe the unfinished nature of this text is central to its charm, dependent upon letting go. I look forward to seeing its final unfinished form!

In this section, I share reflections from my undisciplinary (UD) doctoral journey. I do this in the hope that it might resonate with others, elsewhere, as a particular set of experiences during doctoral becoming. I also point towards some lessons learned from my side during this process, in the hope that it will support in setting conditions for UD research.

13.1 Stories of undisciplinarity

I took a nomadic approach to my research in some ways, moving between different research epistemic and institutional communities. At times, I felt like I was walking around with a backpack travelling through a landscape. Along the way, I collected some things – theories, methodological approaches, impressions of academic politics, disciplinary and field-based approaches to research, a sensibility towards teaching in times of change. I have also explored various research communities as a source of inspiration and in search of a collective identity[46]. As neophytes, *"to enter an academic discipline is to become disciplined"* (Sword, 2012, p. 12). This process, where one is introduced to the logics specific to a community, is instrumental in informing the ontological, epistemological, methodological and axiological basis of early-career researchers (Frick, 2010). Identity-shaping then takes place when negotiating authorship (Leonard, 2010), balancing competing responsibilities (Lin & Cranton, 2005), joining a conversation (Piotrowski, 2017), and relating to an organizational and institutional culture (Frick, 2010).

This UD journey was of course not without its challenges. I have chosen to reflect on two challenges: *learning to collaborate while collaborating, and undisciplinary senses of place*. First, what became clear to me, especially in research phase one, was that this PhD was not only a process of learning about a topic, but it was also a matter of learning how to collaborate together across different levels within academia. Given its undefined nature, more time at the beginning was required for gathering a sense of possibility in research. I arrived at a time when the research group that I was joining effectively doubled in size. As I was in the processes of trying to learn about research possibilities, a new environment and to prepare for PhD life, we

[46] In 2018, I presented at sustainability transitions conference (IST) and attended PhD courses on transitions. In 2019, I attended the STEPS summer school on uncertainty and transitions, the NEST transitions young researchers conference in transitions. I took courses in systems thinking and began engaging with the learning sciences division in Chalmers. In 2020 and 2021, I began to engage in C-Lab intensively, taking courses in education and climate leadership. I also attended the transformations conference 2021, with a focus on searching for points of interest. In 2022, I began to move towards reading courses focused on absences during my PhD, as well as a co-developed PhD course focused on spending time with peers around emerging topics of interest & a seminar on environmental and sustainability education research.

were also collectively trying to plan for joint research agendas together. When I joined, there was something about a broad-to-narrow progression in my PhD that felt appealing, where my research approaches would move from more aggregated towards intense and focused research strategies.

While this strategy held true in some ways, a large systematic review process marked a challenging first two years in my PhD. Temporally, my PhD timeline was wrapped up in different timelines (the timeline of a group, the duration of a post-doc tenure, the timeline of a study). What was in some ways "my project", became entangled in a research group that was trying to learn how to work together. Systematic reviews, especially those that are exploratory, require a significant amount of time and resources. Their reflexive nature means that groups must negotiate boundaries and scope together. Yet, rather than being on the same boat with different views, as part of a group, this early period felt a lot like being on different boats.

Second, although I view the nomadic nature of my PhD in a generally positive manner, its UD nature forced me to constantly rethink my sense of place. When arriving at a research division, PhD students begin to enter social and intellectual environments that shape their thinking patterns, providing insights into the rules of research and expectations in academia (Frick, 2010). I joined a small research group that was part of a much larger research division, which was part of a technical university. The group around me was quite small, and the division felt like a patchwork of different methodological approaches. While the research division provided a vibrant and diverse social setting for PhD life, epistemically and ontologically I felt like a stranger in stranger's land. It was difficult to share my research without me feeling like it was exotic or fanciful, and without experiencing the challenges of putting what I was doing in a box. I frequently felt uncomfortable with the absence of concepts such as power and participation, the absence of agency in education and research, and the absence of conversations around worldviews in science. At the same time, I was on my own journey, trying to navigate uncertain terrain where soul searching is required.

Institutional conditions compounded the discrepancy between my process of questioning, and the lack of answers that my everyday environment provided. In a mandatory PhD course on academic writing, I was grouped for writing exercises with a group who focus on materials science. During a one-on-one peer review exercise, I received feedback from my peer on paper I in this thesis., This colleague, an industrial PhD student studying thermal conductivity of pipes, shared that *"This is a load of shit. It's not science, but you write well".* In mandatory PhD course on Sustainable Development, the central reading material included the following statement *"Natural scientists and engineers need to appreciate social science and social scientists need to understand natural science and technology"*. In the formative years of my PhD, I felt a triple burden. I was trying to find my own way, I felt like I needed to defend my approach at a

fundamental level, and I was in an environment where those most spoken approaches to research were alienating to me.

Over time, my sense of place and purpose evolved, partly since I began search for other forms of community and belonging. One helpful approach for me was to take a translocal approach. I found joy elsewhere, and I began to think through phase two of my PhD with a more active connection in C-Lab. This movement enabled me to re-explore some of the tensions regarding knowledge and power asymmetries that I had experienced, as they manifested in the educational space. It enabled me to connect seemingly disparate experiences to broader systems and institutions, and to better understand their interplay. It also helped me realize that If I was experiencing this, others might have been too. Others might also be trying to change this elsewhere. Over time, I felt a strong need to search for these communities of research and practice outside of the division. This included a research division in another department in Chalmers, collaborations with three research schools during my PhD, as well as series of formal and informal networks that kept me motivated and engaged. I found other nomads, both inside and outside my division, who were working in between in their everyday environments. They instilled a hope in transformation in the university, and the importance of creating institutional safe spaces for these logics. At the same time, they pique my interest in the unique challenges associated with research strategies that are unconventional.

13.2 Reflections on research roles

Sustainability transitions and transformations researchers routinely navigate multiple roles when engaging with real-world agendas (Wittmayer and Schäpke, 2014; Bulten et al., 2021). This diversity stems from the unconventional and creative ways that actors can co-create knowledge for transformative change. I have turned to the distinctions by Brown et al (2010) surrounding researcher relations (Figure 7).

In each phase, my roles iteratively developed in different ways. In research phase one, I was primarily an ID project coordinator as part of a research collaboration. During this phase, my role was to bring together various forms of knowledge and experience as part of a co-produced research design. This phase involved intensive processes of data collection and analysis. I was primarily responsible for structuring collection, organizing analysis processes, and facilitating reflections within the group.

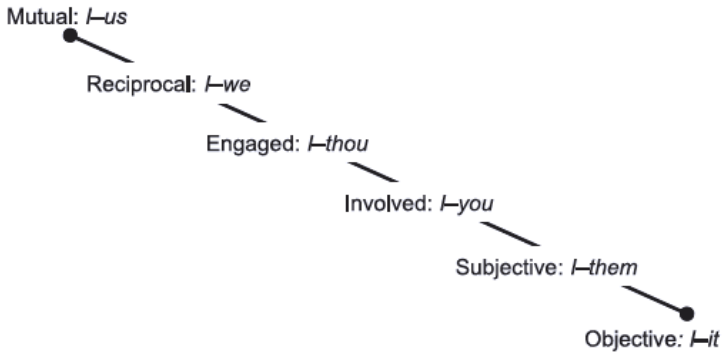

Figure 7: Researcher roles, from Brown et al. (2010)

In phase one, I routinely provided structure for reflecting on the direction of ideas, as well as to relay where all researchers were in the process. This research was highly exploratory, meaning that a central thread centred around managing expectations, as well as bridging mediating views of quality and robustness across all stages of the research process. At the same time, it was the research strategy that was the least intertwined with its subject matter and context. As a result, although my role centred on ID collaboration, it was not a place-based approach to labs in the real-world.

In research phase two, I juggled various roles as part of an exploration into C-Lab. My involvement as a researcher was situated, invested and engaged. My two primary roles were as a curriculum co-designer and facilitator in courses during my PhD. In addition, I considered myself a co-learner as part of the learning environment, reflected in the approach that we took in framing this environment. Connected to paper II, I supported in integrating theoretical and experiential knowledge to jointly develop a research design alongside ID and TD researchers. Given the multiple roles, in combination with the collapsed distance between researcher and case, there were strong expectations that role conflicts could occur in research phase two. It therefore represents the slowest and most embedded form of research, consisting of five years involvement in C-Lab. Decisions to begin to organize around empirical windows were taken collectively, with the knowledge that there would therefore be new interactions between course content, student experience, designer intent and research intents.

In research phase three, I consider my role to be closer to that of an accompanying and reflective scholar. Given the focus on better understanding evaluative practices, I supported in dialogue with evaluators of three cases, one of which overlaps with my praxis in C-Lab. I took a less active role in actively facilitating the co-production process and was more of a co-producer during the framing of the research.

13.3 Reflections on quality in undisciplinarity

While a language exists for established divides of qualitative-mixed-quantitative, there is a need to develop frames for appraising the quality of research that begins beyond discipline (Mitchell & Willetts, 2009). The search for more creative and impactful work partly lies in how we carve out new forms of assessment that are relevant for times of change (Sovacool et al., 2018; Temper et al., 2019). Transitions and transformations research is routinely associated with the "applied" side of research, given its strong multi-stakeholder character. Yet, there is a growing realization that it brings with it exciting questions as a legitimate form of science. Questions such as: What if this research is feeding into design and process, rather than external to it? What if it supports in the reframing of a problem, or the increased capacity to act, rather than policy recommendations? How can we appraise research that accompanies multi-stakeholder processes that co-design, co-produce and co-evaluate? How can we develop a language for connecting various streams of experience and knowledge in a creative manner?

Hölscher et al. (2021) outlines five quality indicators for transformations research. First, this type of research is explicitly **normative**. It is rooted in societal challenges and matters of concern, recognizing its conflictual, power/value-laden, and contested basis. Second, transformations research is **systemic** in scope, intent and process, often carrying an explicit systems paradigm in its works as part of its epistemic basis. Third, its epistemic basis is **counter-hegemonic** with regards to systems and values, with the hope of inviting for new lines of reasoning around knowledge and action necessary for transformations. Fourth and fifth, actionable knowledge sits firmly as a key tenet of **socially robust**[47] knowledge in transformations research, as does a twin ambition to combine an interest in problems with an eventual focus on **solutions**.

[47] It is argued that transitions and transformations research can benefit from an earnest appreciation of the merits of research design, whilst knowing that there are natural limitations to each that we may choose. Political rigour, defined by Temper et al. (2019) can be approached via *"the application of methods of reflexivity in knowledge creation through which power relations and explicit values and aims of societal transformation are identified, reflected on, socialized and evaluated amongst an extended peer community, and reflected in the research design, methodology and research outputs"* (p. 11). Political rigour, rather than rigidly defining the "content" of our knowledge according to criteria, may be useful in inspiring conversations around the nature of one's work, and the role of research as a political and ethical form of action.

13.4 Lessons learned

Undisciplinarity does not mean anything goes. It begins with the conviction that current disciplinary journeys are insufficient for the challenges at hand. Although UD has a strong normative assumption, many UD scholars may remain unaware of its implications. Therefore, UD spaces, processes, and orientations progress in parallel to a prevailing expectation that one must *discipline*. It is a highly uncertain form of both exploration and resistance, where *"the more one strays outside disciplinary frames, the harder it may be to demonstrate one's depth and pertinence of expertise and hence to pursue what is conventionally deemed a "successful" academic career"* (Lyall, 2019, p. 2). It therefore demands that one progressively build structure into their own navigation, where reflection can support in learning about how one learns. Three core capacities in this process are (1) deep grounding in methodology, (2) the importance of being aware of and able to navigate ontological and epistemological differences, and (3) the ability to strategically navigate existing institutional spaces and structures (Haider al., 2018).

Building meta-cognitive skills is necessary in supporting navigating work. Its need arises from making choices that can become overwhelming in dynamic doctoral journeys. For me, this included the need to know when to read, when to design, when to study, when to communicate, when to combine, and when to integrate. Praxis reading (theory-seeking reading in order rapidly inform (1) understanding of experiences, and (2) strategies to act during process) differs from disciplinary reading. It also points towards the need to think through depth versus breadth, individual versus groups, and knowledge and action challenges associated with UD. For example, exchanging between theory and practice requires multiple conversation that bring attention to the politics of research. These include, but are not limited to:

- Where are the boundaries between individuals and groups when it comes to ownership of ideas?
- What principles might underpin collaborative authorships that concern praxis? How do we navigate uncomfortable conversations regarding unclear authorship?
- How are praxis approaches undermined by fast academia, fragmented knowledge practices and impact as citations, and how can such it be protected?

Undisciplinary journeys benefit from creative and diverse inter-transdisciplinary networks. PhD journeys are essentially creative pursuits. This is no more visible in the UD condition, where a heightened sense of exploration brings with it trade-offs and opportunities. Lazurko et al. (2020) provide guidance in orienting oneself when embarking on UD and TD journeys. They argue that recent PhD journeys are marked by four movements:

1. The movement from *Disciplinarity* to *Transdisciplinarity*
2. The movement from *Knowledge Holders* to *Knowledge Brokers*
3. The movement from *Boundary Creators* to *Boundary Spanners*
4. The movement from *Academic Impact* to *Societal Impact* and *Exposure*

Within my PhD, my connection to C-Lab meant that I could develop local and international networks around a shared mission. Along the way, the appeal of C-Lab was a multi-stakeholder appeal, making it possible to engage researchers who routinely balance multiple roles in their daily lives. In addition, meeting like-minded scholars supported me in directing my research around questions, topics or challenges, rather than a concrete discipline. In short, as my network grew, the possibility to entertain and strengthen UD grew too. It included concrete conversations that were not possible from within a discipline. For example, how to apply for funding for TD projects; the importance of sustained engagement before research begins (Pearce & Ejderyan, 2020; Horcea-Milcu et al. 2022); the importance of challenging assumptions and learning to collaborate (Freeth & Caniglia, 2020); the need to welcome tensions when UD (Lotz-Sisitka et al 2015). In addition, it pointed towards the possibility of that which sits beyond discipline at the level of research strategy (Care et al. 2021; Mitchell & Willets, 2009; Sellberg et al. 2021; Moriggi et al., 2020). Finally, these experiences have been helpful for me as they also sketch out the possibilities for early career undisciplinary research. Being surrounded by a diverse and creative group means that I feel comfortable becoming a more creative researcher.

Undisciplinary journeys highlight the importance of adopting a reflexive and caring approach to research. They recruit explicit attention to doctoral identity, knowing that such journeys raise uncomfortable questions regarding the problems and opportunities associated with current knowledge systems. In addition, it points towards the need to nurture caring methodologies that anchor their work around facilitation and communicative skills (Holden et al., 2019). These skills are central in boundary spanning activities and to the co-production of knowledge during processes (Mitchell et al; 2015, Mitchell & Willetts, 2009; Caniglia et al., 2021; Hölscher et al., 2021).

In this doctoral journey, dominant conceptions of research roles have proven inadequate for the type of research I was pursuing. Rather than guiding me, they constrained possibility with assumptions regarding what research is, who it is for and what we can do. There was a perceived expectation that I should expand conceptions of research to make what I have done 'fit'. However, I was interested in building forwards, rather than explaining backwards. Encouragingly, similar expansions are taking place by early-career researchers faced with a realization. The categories regarding what they have done might not have existed before they did them. Rather, they are emergent properties of a transgressive act, a response to absence. To borrow the words of Akkerman (2021), multiple logics are inevitable in a world of complexity

and contradiction. Despite this, doctoral students can *"as much comply to as disregard or oppose what they are offered or expected to do, with capacity moreover, to imagine and create things or find position, purpose, and potential not yet laid out for them"* (p. 419).

Creations include the very emergence of undisciplinarity at the level of paradigm (Haider et al., 2018); early career researchers who have transgressed western research roles that are insufficient for their research trajectories (Temper et al., 2019); collective authorship activities (Care et al., 2021) and chimeric/hybrid metaphors around research (Ahlborg & Nightingale, 2021). These signal the significance of nurturing containers for exploration, imageries based on normativity, positionality and ethics, collectivising authorship to resist the neoliberalization of research, and creatively unbounding research for transformations.

Crucially, such expansions secure the need to continue doctoral research, and research at large, as a process of *becoming*. Given my research strategy, it appeared via a need to reconcile mismatches between the role of education, ongoing collaborative research tempos and the timeline of a doctoral program. In my journey, this mismatch has been approached via questions such as:

- What is the *role of education and research* in transformations, and how can we be a part of this?
- What *type of research matters* in the context of social and ecological challenges?
- How can a *successful and impactful* doctoral journey be thought of? What might *responsible and transformative* research look like?

Universities, divisions, and research schools are crucial spaces for undisciplinary becoming.

> *Transgression would be pointless if it merely crossed a limit composed of illusions and shadows.*
>
> *Foucault, 1977, p. 34*

All UD journeys take place in universities that are often highly disciplined. Although many universities, including my own, currently espouse ID and TD in their institutional missions, they fall far behind in their everyday environments[48] (Lyall, 2019). Of importance during my doctoral

[48] Lyall (2019) exemplifies this contradiction, finding that interdisciplinary PhDs experience a host of tensions that are compounded by institutional conditions. These conditions – such as senior professors who are the most disciplinary, a lack of interdisciplinary soft-skills development, an expectation that interdisciplinarity begins after PhD journey, graduate classes that prioritise expertise within knowledge communities – simultaneously reinforce disciplinary training at the expense of interdisciplinary becoming. Despite the general agreement that interdisciplinarity is desirable, this contrasts with institutions that underplay interdisciplinarity in practice. At best, it sets the stage for a doctoral journey where a flexible interdisciplinary identity is shaped in spite of these conditions. At worst, doctoral students feel like strangers in their division, are evaluated in a disciplinary manner and finish their PhD underprepared to flourish as an interdisciplinary scholar.

journey was the need to navigate existing institutions in search of conditions that promote UD, whilst at the same time recognizing the trade-offs that might occur. This included international networks, numerous research groups within the divisions, as well as connections within C-Lab. It led to a need for me to balance the trade-offs that occur when navigating multiple institutions, as well as different networks. For example, navigating three divisions within one university creates pressure in terms of where to invest your time and energy as a student, and influences one's ability to actively engage in each environment. These situations are like those experienced by TD scholars who have faced the need to balance their ambitions towards societal change, conventional markers of impact within universities, as well as the personal tensions that occur when trying to balance these two (Sellberg et al., 2021). The following challenges highlight the importance of institutional conditions in enabling or constraining ID-TD-UD PhDs. Given the strong integrative work that often underpins such research, these doctoral journeys require more active engagement regarding:

- How to understand and explore different conceptions of *impact and success*
- The role of mainstreaming content such as *generic transferrable skills, and which actual skills are necessary in inter-trans-undisciplinary training*. For me, these included c*reative methodologies, facilitation, knowledge integration, collectively framing societal challenges*
- *Institutional space and support* to construct PhD pathways that co-produce knowledge
- *Supervisory training that* supports *explorative yet critical approaches* to this form of research
- *Incentives for societally relevant research processes,* not only communication efforts
- *Training regarding transformative education and transformative pedagogy,* not only the mechanics of teaching.

13.5 Reflections on citation practices

It is unquestionable that science has generated inequalities in citation practices. This reflects generally held knowledge that female, global-south and minority scholars are disproportionately under-cited relative to the number of such papers in a field. Citations are systemic products, entangled in the logics of impact, success via citation and rapid production. They are also power practices, propped up by self-citing, disciplining and boundary preserving. Engaging with authorship provides a gateway into the uneasiness of privilege, making visible the reality that pragmatic citing may perpetuate inequalities inside academia.

In this thesis, I sought to consider choosing references that reflect the diversity of the field in thought, form of contribution, gender, race, ethnicity, and other factors. Although not perfect, I approached unequal citing by estimating the gender of authors at stages of drafting. Expecting an over-emphasis of western male scholars, I decided to reconsider my citing in the hope of

learning my way forward. What became apparent, however, was that access to questions of "why" were invisible when citing. It felt impossible to consciously cite as I write.

This indicated to me that I needed to do more, otherwise I would remain complicit in denaturalizing the process of making some texts more visible over others. Given that working forwards did not go well, I started working backwards. I questioned central versus secondary references. I made lists of the citations that inspired me the most, as well as those which may have the least to lose. The process led to the removal of many citations, as well as the emergence of others. It noticeably shifted the direction and style of this text, as well as what it draws from. I believe it also enhanced the quality in my work, through access to creative and unorthodox forms of research.

Along the way, I also began to question whether I should have done more to do become aware of, and critical towards, my practices during the writing of the articles contained in this thesis. I began to question why I was a white, male, European, author, surrounded by and writing largely with white, male, European authors, about a phenomenon that was found to be euro-centric in its reach. Contradictions began to appear and intersect, given that I am a product of a universities in the global north, and that the sustainability transitions community also brings with a legacy of Dutch, male thinkers (Chappin & Ligtvoet, 2014).

This strategy was emergent and emotional. It may come with flaws, but it felt important. It is also ongoing. Through a process of critiquing how and why we cite, and in reflecting upon my own process, I aim to witness its relevance. I look forward to future work that could help us to better understand how to support equitable practices in science.

14 A one-tonne PhD? Flight-free academia through a doctoral journey

Picture 1: image taken from a moving train in Breclav, Czech Republic. August 2019

> *It would be no exaggeration to say that academics have worked aeromobility into the ethos of science, in what might appear like a peculiar mix of necessity and romance: Globetrotting is part of the allure of being an academic, but at the same time, academics must fly if they are to 'stay in the game'—or so the story goes.*
>
> *Bjørkdal and Duharte, 2022*

This doctoral journey provides an account of the alternative knowledge mobilities proposed by undisciplinarity, as well as flight-free research that remains expansive. It provides an entrance into the who and what of knowledge practices that might be both expansive and highly mobile. In this chapter, my aim is twofold. First, I draw parallels between an ongoing flight-free journey

and my larger decision to stay on the ground. I do this by engaging in a travelling reflection, a writing story, that accompanies my trip. As I travel from Norway to Ireland and back, I reflect over the various experiences and topics that I associate with staying on the ground. Rather than a discretely organized set of analytical arguments, I focus more on the role of narrative, story and experience in developing my reflections. Fragments have been collected across the duration of my PhD journey; others will emerge through this travelling reflection or as part of other overland trips. Second, I begin to contextualize reflections by considering staying on ground as a response to pervasive unsustainability within academia. This is approached from four primary angles, where staying on the ground functions: (1) as a response to the imagery of the aeromobile academic, (2) as anticipatory critique and reflexive practice and (3) as a source of prefiguration.

I adopt an approach to writing inspired by embodied forms of research such as walkshops and moving interviews. Mobile methods promote new thoughts and layers of meaning to emerge through reflection (Wickson et al., 2022). These reflections transpire through an altered relation to place, as well as the organic terrain that becomes available during train travel. This terrain connects to how we "move" through both epistemic and geographical territories.

Tuesday May 31st 2022

Today marks the first leg of my round-trip journey to Belfast, via Cornwall and Ghent. Over the next 5 weeks, I will make my way across 8000km. I will travel on twenty-nine trains, at least twenty trams, six metro lines and five ferries. With my backpack, laptop, interrail pass, camera, and phone, I will pass across 7 national borders, one EU border and a current (and confusing) border between UK and Ireland.

There are three main reasons why I embarked on this trip. Each destination holds value of a different kind, and each is meaningful to me. But I'll explain more about that later. Taken as a 6-week writing story, this is my most recent trip while staying on the ground. As I will describe below, my decision to stop flying was borne out of a concern for how I can best use my time and energy towards things that I care about. It has been connected to a process of soul searching, and is now intertwined with what it means to do research. Of course, producing knowledge for change can be seen as the currency of what it means to be a researcher. However, the way that we do this can be done in several ways. As Hannah Knox beautifully puts it, the "how" of our efforts to create change through our work are intrinsically linked to the ways that we move.

I can't help but think about how early this starts early for us. That is, how and where we choose to study as students; how and where we engage with other scholars; how and where we speculate around field trips; how and where we engage in and through places for our research. Matters become more complex as we nestle into the international projects and universities abroad that accompany university life. All these moments are at best a matter of choice, and at worst a fleeting thought as part of an ever-busy schedule where obligations increase. They are entangled in the modern mission of the knowledge economy, and I am no exception to this.

The decisions about how we move during our research provide a rich entry point into aspects of academia that are rarely considered or problematized. After all, academic mobility is not simply a practical outcome of scholarly life. It regularly feeds into the ambitions of research and education, and influences views of success and impact. How we move is therefore an essential component of how we "perform" research. These choices are ethical, and often embody the values that guide our conduct. By considering one's own mobility, and by experimenting with mobilities as researchers, it may become possible to strengthen our own disruptive capacities for transformations.

Tuesday May 31st, 2022

The first leg.

The train has just crossed the border between Norway and Sweden. The wi-fi is off and phone reception, sketchy from the start, cut out around 5 minutes ago. A luggage rack above my head rattles and flexes, making the same noise for the past 2 hours. An almost uninterrupted treeline zooms by. The landscape is undulating, exposed and, at times, hypnotic. After a while it loses its appeal, resembling a blur of green of yellow. These sounds and sights are familiar to me; this is not my first train ride, nor is it the first that I have taken between Norway and Sweden. In fact, since 2018, I have crossed the border no less than 30 times. This time I will continue the trip to Gothenburg to a larger journey, one that begins in May and finishes in July.

Given that today marks day one of my journey, and I find myself naturally wanting to look backwards. An uncomfortable truth comes to mind. Aero-mobility has actively shaped how I have moved in the past. I live in Sweden, but my near and distant family belong to Belfast, Ireland. I am a product of an international masters' education, yet I have very local connections and roots. My partner is from Norway. Some of my closest friends live closer to home, but not quite; with others, I try to stay connected via social media, postcards, visits when possible or the occasional zoom or skype call. I have active collaborations with researchers based in Germany, Canada and South Africa. In 2014, I moved to Lund, Sweden. During my time there, flying made it possible for me to create international experiences with friends. In 2016, I moved to Brussels, Belgium. During my time there, I flew home to Belfast, Dublin and Larnaca for family; I connected with old friends in Amsterdam, London, Norwich and Edinburgh. I flew to Thessaloniki to present at my first conference, to Oslo as part of a European project and to Graz to support a research collaboration. I sustained a long-distance relationship in Oslo, with back-and-forth trips along the way. My web of relations was growing, as was a perceived need to fly in order to stay connected.

In 2018, I moved to Gothenburg to begin my PhD. In that year alone, I flew to Brussels, Bonn, Bratislava, Dublin, Edinburgh, London and Manchester. I attended a conference; I visited my family and I attended the wedding of a close friend. The factors above – a dispersed social network, international education, long-distance relationship, concentrated family, and international research commitments – all represent the specific conditions that shape how and why I move. Most of my historical travel can be connected to one or more of these factors. What's more, even though it's been 4 years since I stopped flying, these conditions still exist.

At the beginning of 2019, I decided to do it. Just after Christmas with family, I made the decision to stay on the ground. There was no end date as part of the plan, and no grand reason for why

that time felt right. It just did. I recall that the decision not to fly was one that I did not take lightly. I had been thinking about the idea of changing how I move for several years, but I don't think I was prepared to rethink what this might mean. Looking back, this decision was also at a time when I was searching for guiding values as a researcher. It connected to the sense that, when reflecting upon the imprints I leave as I move, *"I'm actually a quite different person, I just never get around to being him"* (Von Horváth, in Rosa 2013).

Picture 2: Hamburg train station, platform in direction towards Berlin. July 2019

14.1 Intersections

I have written this entry in 3 parts. Each part links to a connecting trip as I passed through Hamburg, Germany. When travelling from Northern Europe to Ireland, there seems to be one constant: spending time in Hamburg central train station. Since the beginning of this PhD, I have been at this station no less than twenty times. Each and every time, Hamburg has been an intermediate stop as part of a professional or personal journey, and never a final destination. Hamburg station has always been a place of mixed emotions for me. It has often signalled that I can drink beer in public places. It has also tempted me into buying pretzels and bread while waiting to move on. At the same time, those trips are regularly tight, delayed, or cancelled. I bring with me a readiness that dilemmas may occur, that there are windows of opportunity, but they are often short, and that I will need to think fast in order to adapt. I also bring a strong sense that many things are out of my control when I am here. As a point of connection, its location on each trip that I take serves as an interesting metaphor for the intersections that accompany staying on the ground.

Wednesday June 1st, 2022

So, how does my choice to stay on the ground intersect with my professional and personal life? In the case of my journey to and from Ireland, I planned this trip in order to manage competing personal obligations with an opportunity to connect around the research topic of education. The trio of wedding, seminar and birth marks its beginning, mid-point and end. The first time I passed through Hamburg, I was on the way to Cornwall to celebrate the wedding of two dear friends Richard and Hannah. I had planned to write about the uncertainties of the trip along the way, given that I had never travelled to Cornwall and was worried about being delayed for the event. My friendship with Richard goes back to secondary school in Belfast, and over the last 15 years we have dovetailed at important moments in eachother's lives and those of our near circle of friends. It's a friendship that clicks when we meet. It is as if we never change. At the same time there is a clear sense that our lives are constantly in motion in between meets, and that things have changed. Richard is now a husband, and since his marriage in June he has become a father for the first time. In the middle of the celebration, we spent time to stay with something that we normally don't do. As we stood in the barnhouse, surrounded by friends, we reflected on the fact that things are actually changing. That we seldomly see eachother anymore. That there is pain and sadness connected to that. Time flies by, and globalized worlds enable the sort of friendships where people can live far apart and still see eachother frequently. Ironically, we were surrounded by friends and family who has flown in the day before the wedding and will "head back" the day after. For me, I won't be heading home for five more weeks.

Saturday June 18th, 2022

The mid-point of this journey brought me to Ghent, Belgium, as a participant in the seminar for Environment and Sustainability Education research. I was a newcomer to this community having never been to an educational seminar conference. The importance of transforming education had been growing in my work for some time, however. I had been exploring critical pedagogy, caring educational praxis and transformative missions of the University. I had also been engaged with others in Challenge Lab for some time, and felt the time was right to explore the education community given that my background is not in learning or educational sciences. The seminar was wonderful and refreshing for many reasons, but four moments come to mind.

First, we practiced digital detoxing during our time together. For me, this made me feel still at a time where I had been travelling quite extensively. After 24 hours on a boat, train, train, bus and tram, the contrast between the travel and the setting was almost therapeutic.

Second, throughout discussions across groups there was an apparent sense that speed and urgency matter. It is the first seminar where reflections have touched upon care in research, slow academia, or the need for speed in our work. More importantly, there was a growing awareness of the tensions and trade-offs associated with slowing down. This was echoed by participants whose reflections on speed wandered from the university and made their way to the supermarket, fast cooking, fast travel, fast media consumption. They veered towards parenthood and research, towards gender and mobility, towards justice and carbon inequality. Not only is there an urgency attached to climate change, but speed seems to have an addictive influence over everyday life. Over time, reflections began to crystalize. Speed in academia is

entangled with the speed of everyday life. It's a systemic challenge, and one of multiple systems at the same time. How then, if publishing an article, travelling, and cooking food are entangled in logics of speed, is it actually possible to slow down? What are the consequences of slowing down in our work, and what new avenues become available to us? What does this mean for education? These questions are unanswerable for many, partly because how unfamiliar they are within academia. We don't know what it might mean, and there is an unavoidable character that "not knowing" will accompany conversations around flight-free academia.

Third, were the stories of how we "got there". Not only in our careers, or across research fields, but also physically. I recall exchanging horror stories with colleagues about train rides that have gone wrong (and there are many). We shared our favourite stations and exchanged on why we avoid flying. I also recall the uncomfortable but important conversations around privilege and proximity in academia. There is a necessary contradiction here that is important to stay with. Although I and others have decided to stay on the ground, the conditions for mobility within Europe make this choice possible for us. Rail networks, secure contracts and flexible working arrangements mean that I can avoid flying. For others, such possibilities are for the future, and therefore flying exists as the only option.

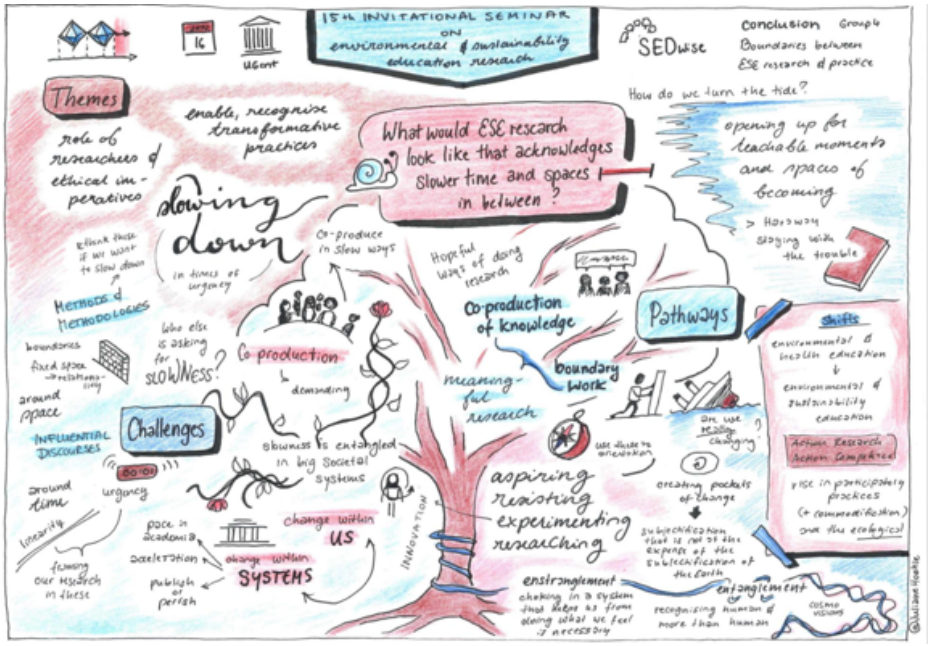

Figure 8: ESE Seminar visual summary of session on boundaries between ESE research and practice. Credit: Juliane Hoehle, 2022

Friday July 8th, 2022

As I pass through Hamburg for the second time on my way back to Norway, a lot has happened. This trip back has been stressful day, and intersections can be complex and complicated. It is a completely unfamiliar route, which brings a lot of uncertainty regarding how things match up. To get here, I relied on a train from Liverpool – London, a train from London- Dover, a ferry from Dover-Calais, a train from Calais-Hazebrouck, and a bus from Hazebrouck to Lille all aligning yesterday. I think about my time in Belfast, I became an uncle for the second time, to a healthy and happy little girl, Rose. Spending time in Belfast is always an interesting experience, full of new choices. I bought a second-hand bicycle and cycled for the first time in the city. This meant

that I could avoid car trips, and that I could explore and continue something I love doing at home. Belfast is home, but at the same time I left 8 years ago. Now that I fly less, I also travel back less. The journey from Norway or Sweden to Ireland is at best a 40-hour trip, and it's tiring. During my PhD, I have travelled home by train twice. I feel a weight of obligation, as the family member who left, it should be me who visits home. If I encourage family to visit me and to experience my life, my relationships continue to embody co2 emissions at a factor that exceeds my own sacrifice. To me, this is the crux of any decision to stop flying. Contradiction will follow, and it's impossible to understand the impact that your choice will have on yourself and those around you.

By deciding not to fly, I had made a commitment to travel on the ground. What is becoming more and more apparent is that not flying is feeding back onto me via my relationships, as well as the systems within which I am embedded. Not flying means then rethinking the role of mobility in my personal and professional life. Over the last few years, friends and families have grown. I became an uncle and godfather, my closest friends have found love and committed to eachother, and the lives of those have continued around me. I've increasingly been confronted with the feeling that I cannot keep up with these developments, given that any trip home takes 48 hours minimum. Whilst I can nurture my networks within academia and make considered choices about where and how to spend my time, staying on the ground brings with it an emotional toll. It brings with it the worry that I will miss milestones in my family's lives, that I will become less available physically and emotionally. In many ways and to many people, it signals a withdrawal from a world that is obsessed with speed of movement.

In my life, there have been two enablers for international friendships. Firstly, and perhaps more harmless but still not perfect, I have been able to sustain relations through social media, facetime, skype and more recently, zoom. The second enabler has been the flexibility provided by flying. My friendship with Richard, with my family, and with colleagues, like many of my relationships from home, has needed flying if new memories are to be created into the future. Staying on the ground has started to change how I move, meaning that in order to maintain relationships, I need to synchronize them in a way that I have never needed to before. This trip is a perfect example of the imperfect nature of not flying in a world where things come fast. As I travelled home to celebrate the wedding of friends, and as I reconnected my family, I began to realize that celebrations and milestone occasions may be all that connect us moving forward. I also find myself wondering how I can navigate these intersections into the future, knowing that my social worlds are in motion. They are expanding. In the time that I have wrote this thesis, I have become an uncle for the third time, to a future world-builder called Marco: I have been invited to a family wedding next year; I have been arranging for my family to attend my thesis defense, knowing that I will not travel home this Christmas for the third consecutive year. An inability to be hypermobile means that I need to adapt my own circumstances to fulfil social, family and research commitments. The intersections in Hamburg seem to be most complicated, yet least complex, of those that have accompanied my writing story. Yet, both legs were delayed.

14.2 The final leg

The reflections were drafted on the night bus from Copenhagen to Oslo. Trips of this length, combing major life events and professional networking opportunities, can be overwhelming. My strategy of combining all three may have worked this time, but I may not do it again. If linking multiple journeys is challenging in this way, then other strategies might be necessary. For example, I might localize my academic network, and adopt a translocal approach to conferences via digital participation. When I think of why this trip was so challenging, what comes to mind most is how travelling by train and bus can quickly ruin an experience. Countless times, I have found myself in search of water or fruit at train stations, only to be presenting with sweets, fast food and coke. I spent 10 minutes trying to find a Banana in Euston Station, London. When I arrived in Lille at 11:30pm, I found stations closed, toilets closed, public spaces closed. My night bus was scheduled at 1:30am.

In the very short term, there is a sense of happiness that this journey is over. If staying on the ground requires creativity and inspiration, many of the infrastructures that provide alternatives can suck the creativity from the trip. Along the way, I found myself wondering about the absence of:

- Art
- Play
- Children
- Healthy environments
- Music
- Water to refill
- Barista carts in stations that can fit coffee flasks on their drip tray

I also found myself wondering about the presence of:

- Commerce
- Work
- Adults
- Unhealthy environments
- Frantic silence
- Soft drinks
- Barista carts in stations that cannot fit coffee flasks on their drip tray

I find that UK environments have a blurring effect on the part in-between each stretch. This monotony was helpful as it meant that I could focus on working. At the same time, the increasing blurring of movement through space and time have led to a stronger need to block out distraction. In combining a family milestone, a personal milestone and a professional experience, I felt an interesting sense of worry along the way that if something goes wrong, everything would collapse. Fragmentation in flight-free journeys have this interesting ability to place the responsibility of the trip on the individual, and I felt it this time more than before. I find myself reflecting on the time that it took to plan this journey in comparison to booking a flight,

the time taken to move in comparison to a flight, as well as the physical and emotion weight of this trip in comparison to a flight. At the same time, I find myself reflecting on the choice to stop flying as one of privilege, as a white male from the northern hemisphere living in a densely connected rail region.

As I think beyond this trip, four broader reflections regarding staying on the ground have started to come through. First, I have noticed that train travel is routinely associated with popularized understandings of when the formative years of life are. I found myself meeting people from diverse age-ranges and backgrounds on interrail trips. I felt this sense that formative years are associated with this view that one "discovers themselves through other places". Second, I notice that staying on the ground can be squeezed and compressed into one form. There is no one way to reason around how we move. Not flying, flying less, reconsidering flying, and even cycling, are all part of the same conversation. Third, I think about the importance of story and solidarity as sustaining elements of these choices. Staying on the ground is plural, and each individual experience and narrative, whether intended or incidental, contributes to a much bigger story.

Fourth I find myself confronted by threads that have followed my journey.

How fragile and insignificant these commitments can feel when broader narratives become visible

- The normality of flying for various reasons within family and social circles
- The sentiment that this is temporary
- The associations between "not flying" and "not living"

Three difficult levels of conversation around this choice, both for myself and with others

- The difficulties of maintaining and staying with conversations around flying
- The difficulties of challenging those you care about, and how to navigate the contradictions that lay beyond information-deficit
- The difficulties of celebrating this way of moving, whilst at the same time grieving pieces of the world I may never experience

14.3 The (nearly) Flight-free PhD – contextualising my journey

In this chapter, my writing story so far has focused on episodic accounts of a train journey that I took in June and July 2022. This journey is naturally linked to my broader ambition of staying on the ground, a commitment that I made in late 2018. My decision was borne out of both concern and curiosity. Since then, I have engaged in flight-free mobility for four years. To learn more about what it means to stay on the ground, I have made two decisions. First, I decided to begin tracking emissions estimated by my travel, to learn more about the relative differences associated with these modes. Second, I wanted to explore staying on the ground as a practice that includes emissions but is not limited to it. Therefore, I have engaged in frequent conversations about flight-free academia and been reflectively writing to add layers to my understanding. I have done this to position my choices and experiences within broader social contexts, recognizing that I cannot speak for all researchers.

Since 2018, I have travelled circa 67,000km (See Table 8) during my PhD, and emitted 4tCo2 from how I move. Not all these emissions are associated with my research life. Including conferences, summer schools and research trips, mobility-related emissions from my PhD sit at 1,2tCO2 from 15,000km of travel. But as you can see, life continues alongside a PhD. Given that I am an internationally educated researcher from the global north, with dispersed professional and social networks, my life embodies emissions that may not be articulated by focusing on research emissions. In my case, visiting my family and friends, travelling and exploring the world will continue to play a role in how and where I move. It is confronting that despite my attempt to change how I move, circa 75% of my mobility emissions are not research related. For me, this also highlights that there are clear limits to relative reductions in emissions. With the time and energy to sustain a more connected and humble way of moving, a realization for me is that changing how I move brings with it important questions about why I move.

I feel it is important to clarify some points, before I proceed. First, there is no one way to interrogate how we move in knowledge practices; there is no one way to be a change agent. Neither possibilities of staying on the ground, nor the consequences of flying, are equally shared. Second, dividing research and non-research roles can hide the interconnectedness of how mobilities of knowledge and everyday life. Research is a way of being in the world, wrapped up with how we live with integrity. Third, although staying on the ground can also be a highly mobile practice, it brings with it deeper questions on whether the distances implied are necessary, fair and responsible.

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO2 Non-flight	CO2 from Flight	Flight equivalent kgCO2	Total C02
IST 2018 Conference	Gothenburg	Manchester	Jun-18	Flight	1000		164		
	Manchester	London	Jun-18	Train	315	14			
	London	Bratislava	Jun-18	Flight	1280		201		
	Bratislava	Vienna	Jun-18	Bus	130	7			
	Vienna	Gothenburg	Jun-18	Flight	1090		180		
					3815	**21**	**545**	**545**	**566**
NEST Young researchers conference, Lisbon	Gothenburg	Lund	2019-03-31	National Train (Electric)	300	2,8		848,9	
	Lund	Copenhagen	2019-03-31	National Train (Electric)	60	0,5			
	Copenhagen	Rödby	2019-04-01	Coach	160	4,5			
	Rödby	Puttgården	2019-04-01	Ferry	20	7,6			
	Puttgården	Hamburg	2019-04-01	Coach	150	7			
	Hamburg	Köln	2019-04-01	National Train	425	19,7			
	Köln	Brussels	2019-04-01	National Train	220	10			
	Brussels	Paris	2019-04-02	National Train	108	14,1			
	Paris	Paris	2019-04-02	Local Subway	6	0,25			
	Paris	Hendaye	2019-04-02	National Train	800	37,85			
	Hendaye	Lisbon	2019-04-02	National Train	930	40			
	Lisbon	Merida	2019-04-17	Coach	280	10			
	Merida	Madrid	2019-04-17	National Train	340	19,4			
	Madrid	Barcelona	2019-04-17	National Train	600	27,5			
	Barcelona	Lyon	2019-04-18	National Train	600	17,5			
	Lyon	Brussels	2019-04-18	National Train	730	33,8			
	Brussels	Copenhagen	2019-04-18	Coach	930	30			
	Copenhagen	Lund	2019-04-19	National Train	60	0,5			
	Lund	Gothenburg	2019-04-19	Coach	300	2,8			
					7019	**285,8**	**0**	**848,9**	**285,8**

Table 7: Comparison of two conferences my first PhD conference in Manchester, England (2018) and an early-career researcher conference in Lisbon, Portugal (2019)

Here, I begin to contextualize reflections by considering staying on ground as a response to pervasive unsustainability within academia. This is approached from three primary angles, where staying on the ground might function as: (1) a response to the imagery of the aeromobile academic, (2) anticipatory critique and reflexive practice and 3) a source of prefiguration.

From small to large: Confronting the imagery of the aeromobile academic

This writing is at a time when aeromobile academia has been in full swing for some time. Bjørkdahl and Duharte (2022) notes that as part of the explosion of aeromobility in western societies, academic aeromobility can be understood as an uncomfortable romance. On the one hand, there are calls to critically rethink the role of research in times of climate change, including knowledge practices and researcher responsibilities. On the other hand, academic institutions, both through their research and educational missions, find themselves addicted to flying. Those actors who make choices to stay on the ground do so within research divisions that may be more ambivalent or invested in the mobilities of research. For many, the compulsion to fly presents itself less as choice and more as necessity, wrapped up in the mobilities of everyday life in large. How we move in the production of knowledge is therefore entangled with who we are, both as researchers and as people. At the moment, the dominant imagery is that of the aeromobile academic.

Our lives as academics are shaped by parallel modes of mobility such as hypermobility. In the words of Cresswell (2014) and Sheller (2022), hypermobile academics are a form of 'kinetic elites'; an exclusive, powerful and global workforce whose identity is predicated upon forms of mobility. In the case of academia, elites can also be useful in relating to the way in which academic claims to knowledge are routinely elevated above every day, tacit or lay knowledge. In addition, kinetic elites are complicit in knowledge and emissions inequalities, where our movements are often achieved at the expense of others. This is no more visible in the contradiction that lies with hypermobile climate scientists who travel around the world, yet whose carbon-intensive lifestyle has implications for those who are affected most by climate change. Connecting to the words of Cresswell (2006), many research choices are however just that: **a matter of choice.** Kinetic elitism points towards the inevitability of academic processes to conflate with the ambitions of a tourist, where presenting at a conference is intrinsically linked with seeing new parts of the world.

Some of my experiences point towards a contradiction that is ever-present in universities. There is a tension between three ongoing missions: (1) the universities ambition to foster and expand international networks, (2) the commitment to rapid decarbonization, and (3)

the missions of higher education. Within my own university, there is a clear ambition to brand oneself internationally, as well as to prioritize international research and education. There is an ongoing commitment to local and global sustainability challenges. Yet, all of these aims converge when it comes to mobility. For some, they may even seem at odds with one another. Uncomfortably, the missions of internationalization, education and sustainability embody emissions into the long-term that are completely unarticulated. They exist neither in conversations regarding researcher identity, nor during the development of international courses. Glover et al. (2022) point towards the 'absent presence' of university policies, where air travel remains absent from conversations, but sustainability is heightened in presence.

Staying on the ground as anticipatory critique and reflexive practice

> *The urgency of the climate crisis presents academics with a call to confront their flying habits, and that this confrontation must include an attempt to identify pathways towards a more sustainable academic enterprise*
>
> *Bjørkdal & Duharte, 2022, p. 10*

> *If transformation is about change from the inside out, researchers are called to intentionality and conviction, embodying the values they preach in profound and significant ways*
>
> *Moriggi et al., 2020, p. 14*

I have found the work of Hannah Knox (2022) to be helpful in living with the uneasiness associated with flight-free conversations in academia. Knox reflects on the ways that not flying can provide points of re-entry into knowledge practices as anticipatory critique. For her, the choice to stop flying became a way to critically reflect on broader questions around the sorts of knowledge systems that flying sustains, seeing *"the decision not to fly as not only a moral choice, a practical decision, or a political act but perhaps more important a form of situated reflexive practice that opened up new questions about participation, access, equity, ethics, and the politics of knowledge"* (p.164). For the author, this included lines of reasoning regarding whether some flights are more necessary than others, as well as reflection on the privileges attached to euro-centric views on academia and flying.

Rather than creating divisions between the types of knowledge and values that guide my personal and professional life, I relate to the concept of "living life as inquiry" (Marshall, 1999). Here, Marshall articulates a view of inquiry as embedded in personal and professional ways of being. These ideas resonate strongly with me as they point attention towards the continuous way that we navigate institutional and cultural norms. Here, Marshall denaturalizes research as politics *"Research is also a "political process" in many ways. Who researches and how; whose experience is researched and how that is named or categorized; what discourses gain currency and hold power; what forms of inquiry and writing are favoured by "mainstream" powerholders; and many more are political issues? "Creating knowledge" is political business. Living practice is thus politicized"* (p. 157).

Through my own experiences, as well as the positions offered by Knox, it has become clear to me that conversations around flying and academia are so much more than technologies and policies. There is no single resolution and sometimes not a patently right or wrong choice. The reflections above are my own and speak to no single truth or angle. It also highlights the generative possibility that lies in experimenting with one's own practice, and re-entering the practices of flying alongside others who may have different conditions. For me, turning to staying on the ground as a source of critique has proven illuminating as:

Institutional critique – It has exposed me to the interplay between my own knowledge practices, ongoing incentives structures in universities and the most efficient/convenient forms of mobility.

Identity development – Reflexive engagement with flight-free has allowed me to explore this way of "doing research" alongside my own development as an early-career researcher. This process opens up lines of inquiry such as:

- How do I sustain international connections where projects might imply aeromobility?
- How do I situate flight-practices alongside my own life and the lives of those who I care for, knowing that flying has sustained a way of living and being in the world?
- How do I enter academic conversations around practices where flying is implied but not articulated?

Examining privilege – My choice to stop flying has meant that I have become more aware of how others around me move as part of their own lives. As highlighted by Knox (2022), committing to hard conversations regarding flying has meant that I have also been faced with the realization that the possibilities for change are not equally shared within academia. As a western academic with mostly European networks, it reaffirmed that these choices would be constrained in different ways depending on my own context. Although my reflections highlight that the choice to stay on the ground does come with complications

and challenges, these challenges also co-exist alongside the complex lives of others. By examining privilege, my hope is that I can approach conversations around flying that balance the urgency to act, with the vastly different circumstances that we may have.

For me, staying on the ground, and exploring this choice functions as a mode of reflexive practice, therefore makes it possible to better understand ones one subjectivities amongst others. As mentioned before in chapter 2, reflexivity alludes to "*the capacity of the researcher to acknowledge how their own experiences and contexts inform the process and outcomes of inquiry*" (Etherington, 2004, p. 32). This view promotes a reconsideration of practice, rather than a fixed position but as an unfolding logic that is being structured as it is being practiced.

Staying on the ground as a source of prefiguration

In exploring how individual actions are entangled within systems, I have turned to staying on the ground a prefiguration. Prefiguration can be understood as "*the attempt to create change 'here and now' through the construction of 'local and collective structures that anticipate the future liberated society*" (Boggs, 1977, p. 103). It brings attention to the performativity associated with alternative knowledge practices, as well as the need to live out visions in the present. Rather than waiting to become a better person, to live in a more sustainable world or to align conduct with values, prefiguration responds to undesirability by performing alternatives in the present. Temporally, it inverts the norm by acting the future in the present; it prioritizes practice over theory, and creation over prediction. According to Maeckelbergh (2011), as something that people 'do', prefiguration acts as direct theory towards a world in the making, one full of multiple goals and potentials.

Although associated most with social movements, prefiguration may provide an action-account of staying on the ground that points to the essence of why staying on the ground appeals to me. For me, the value in choosing not to fly is that it comes about via the performance of alternative ways of doing research. It represents a form of agency expression that is at the same time obstructive and constructive. Staying on the ground can be understood as a way of resisting unsustainable modes of doing research and being in the world. Rather than waiting for new systems to exist, staying on the ground as prefiguration suggests that action can 'prefigure' how one might do research in the future. In own journey, prefiguration has entered as a way to reason around why staying on the ground matters, despite the obvious inconveniences that it may cause to dominant ways of doing research. After all, this choice runs in parallel to my choice to stay on the ground in general, and it also runs alongside systems that sustain flying as the norm in my context.

As highlighted by Yates (2014) prefiguration is an experimental practice, implying the need to explore and nurture how such actions may be carried out in the future. In addition, staying on the ground as prefigurative practice suggests that the processes of attempting to live the future in the present surface how new rules and conventions may be necessary for such change to become the norm. Out of the prefigurative practice might emerge the structures, guiding values that underpin the new, as well as a restructuring of practice in a way that expands its possibility. The power, and potential failure, of prefigurative approaches lies on its ability to provide values that may guide the development of new strategies and systems over time. It asks the question: *under what circumstances may this strategy manage to scale up and lead to revolutionary social change?*

Along the way, I have found myself asking whether this choice is realistic, reasonable, or responsible. I have also received these questions from others, both colleagues and family members. In addition, it has supported me in seeing resistance as a joyful practice, and as a search for something better. From a prefigurative view, then, flight-free academia is underpinned by not only the practice, but by new forms of social relations, decision-making and experiences that it may offer a glimpse into. These elements become visible through the process of resisting aeromobile academia, and in attempting to construct new imageries for change. For example, this doctoral journey provides an account of the alternative knowledge mobilities proposed by undisciplinarity, as well as flight-free research that remains expansive. It provides an entrance into the *who* and *what* of knowledge practices that might be both expansive and highly mobile.

Concluding remarks

The writing of this thesis has taken place at a time when transformations are sought after. Despite calls for the fundamental changes in systems, there are unavoidable uncertainties regarding their directions of and magnitudes.

Throughout this thesis, my interest has been with labs as pockets of transformation. It centred on the central aim: *to investigate how sustainability-oriented labs could be unpacked, designed and evaluated in the context of sustainability transitions and transformation*. Across this work, we approached this phenomenon from afar, in the thick of it, and alongside others. In some ways, this thesis has made progress by responding to its four research questions. In other ways, new lines of inquiry have emerged along the way, connected to a practice that is in motion. Therefore, there is arguably more to say and do regarding labs and change, *not less*. I would like to conclude with three points:

First, although transitions and transformations are needed, their scale of change can prove difficult to conceive of and engage with. Labs encourage place-based experimentation, creating a local connection to translocal and global sustainability challenges. They provide a way to approach issues with people, through the development of learning spaces. Rather than saying that we know which direction we need to move in, such spaces make it possible to work with direction in a conscious manner, to imagine the future and re-connect with our lives. They rest upon, and at the same time highlight, a highly collaborative model of approaching complexity. Their processes highlight the need to live with complexity in context in an ethical manner, rather than to move forward. At the same time, not all labs might be equal, not all might be necessary, and not all are motivated by sustainability or research. In addition, there avenues may exist for each of the needs above. This thesis began with a larger sample, and gradually moved away from some practices and scales, in favour of others. Specifically, it moved towards those which educate and engage, empower and govern, and explore and share.

Second, rather than a logical intervention from which change might spring, value may lie in conceiving these spaces as invitations. Framed as invitation, labs invite for alterity within systems, for futures and through education. Invitations, as ethically-informed epistemology, invert the relation between ethics and knowledge, making way for emergent forms of ethical practice. They carry a broad view that, if we reconfigure the basis for being together, new things may emerge. This includes who "we" are, given the asymmetries and inequalities that pattern dominant knowledge systems. Throughout extended experience in C-Lab, we have learned that such practices have the potential to redistribute power and flip

assumptions in learning environments. They highlight the ontological task at hand; to not only accumulate more knowledge and hope for action, but to act alongside others in search of something better. Although scales may be modest, I am reminded of the words of Guenther (1962) that it seems that *"small parts of the universe have a reflexive capacity larger than the whole*" (p. 383).

Finally, this research has emphasized the importance of transformative praxis. It brings with it the confronting realization that we as researchers need to think deeply about our roles in change processes. We may need to look inwards, knowing that transformations may require us to search for guiding values compatible with the challenges of our time. The reflective layers of my research journey bring me closer to the emotional and personal factors for pursuing a career in academia. They instil a belief that academia can be a force for good, but that it needs to be better; that collective capacities to prosper in action-oriented research can be fostered, and they require care together; that teachers and students can dissolve boundaries and create transformative learning spaces, and that it requires different relationships to form; that students have the capacity to institute change in the here-and-now, and that it can be connected to their own learning process; that we can carve out new emotional and relational spaces within academia, and that it can lead to more transformative impact. Many of these beliefs are shared by others, as part of deep questioning about the role of research and education for the future.

Moving forward, I find myself motivated by the following three commitments: (1) *transformations are needed, and labs provide entrance in between dualisms*, (2) *invitations offer the possibility of flipping big assumptions and ethical practices*, and (3) *transformations presuppose fundamental change in what research is, and who it is for*.

Gavin, November 20th, 2022, Gothenburg

I wish we could live the rest of our lives on these rocks,' I said. 'Why isn't it possible to just live at the edge of both, the ocean and the land

Of course I knew why. The edge was an uncomfortable and dangerous place for both of us. The rocks were nowhere to live. I had wanted him to come to my world for that same reason.

'One day these rocks won't be here,' he said. 'The ocean will waste them away.'

'Then we could find new rocks,' I said.

'Eventually you have to choose,' he said. 'That's how the story has always been and that's the way it will be forever.'

'But why?' I asked.

'Well,' he said, thinking, 'I guess because the choice is always there.

Melissa Broder, The Pisce

Table 8: Itinerarium vitae of Gavin McCrory, 2018 – 2022. Entries in * denote research-related travel

Trip info	Origin	Destination	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Easter	Gothenburg	Oslo	Apr-18	Bus	390	21,6		
	Oslo	Trondheim	Apr-18	Train	545	5,5		
	Trondheim	Oslo	Apr-18	Train	545	5,5		
	Oslo	Gothenburg	Apr-18	Bus	390	21,6		
					1870	54,2	0	
Visiting friends	Gothenburg	Copenhagen	May-18	Electric train	360	3,3		
	Copenhagen	Bonn	May-18	Flight	658		107	
	Bonn	Gothenburg	May-18	Flight	837		136	
					1855	3,3	243	
Transitions PhD Course*	Gothenburg	Copenhagen	May-18	Electric train	360	3,3		
	Copenhagen	Gothenburg	May-18	Electric train	360	3,3		
					720	6,6		
IST 2018 Conference*	Gothenburg	Manchester	Jun-18	Flight	1000		164	
	Manchester	London	Jun-18	Train	315	14		
	London	Bratislava	Jun-18	Flight	1280		201	
	Bratislava	Vienna	Jun-18	Bus	130	7		
	Vienna	Gothenburg	Jun-18	Flight	1090		180	
					3815	21	545	
Holiday to Scotland	Gothenburg	Glasgow	Jul-18	Flight	1030		164	
	Glasgow	Gotheburg	Jul-18	Flight	1030		164	
					2060	0	328	
Trip to London	Gothenburg	London	Oct-18	Flight	1030		164	
	London	Gothenburg	Oct-18	Flight	1030		164	
					2060	**0**	**328**	

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Visiting friends	Gothenburg	Bonn	Nov-18	Flight	837		136	
	Bonn	Gothenburg	Nov-18	Flight	837		136	
					1674	**0**	**272**	
Home for Christmas	Gothenburg	Dublin	Dec-18	Flight	1241		202	
	Dublin	Belfast	Dec-18	Bus	168	4,5		
	Belfast	Dublin	Dec-18	Bus	168	4,5		
	Dublin	Gothenburg	Jan-19	Flight	1241		202	
					2818	9	404	
Leverage points conference*	Gothenburg	Copenhagen	Feb-19	Electric train	360	3,3		76
	Copenhagen	Rödby	Feb-19	Coach	160	4,5		
	Rödby	Puttgården	Feb-19	Ferry	20	7,6		
	Puttgården	Hamburg	Feb-19	Coach	150	7		
	Hamburg	Luneburg	Feb-19	Train	50	2		
	Luneburg	Köln	Feb-19	National Train	425	19,7		58
	Köln	Hamburg	Feb-19	National Train	425	19,7		58
	Hamburg	Kiel	Feb-19	Train	109	4,9		76
	Kiel	Fredericia	Feb-19	Train	223	12,4		
	Fredericia	Copenhagen	Feb-19	Train	219	12,4		
	Copenhagen	Gothenburg	Feb-19	Bus	360	3,3		
					2501	**96,8**		**268**
Visiting previous colleagues	Gothenburg	Brussels	March-19	Flight	906		148	
	Brussels	Ischgl-SEE	March-19	Bus	900	49		
	Ischgl-SEE	Brussels	March-19	Bus	900	49		
	Brussels	Gothenburg	March-19	Flight	906		148	
					3612	**98**	**296**	

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
NEST Young researchers conference*	Gothenburg	Lund	March-19	Electric train	300	2,8		
	Lund	Copenhagen	March-19	Electric train	60	0,5		
	Copenhagen	Rödby	April-19	Coach	160	4,5		
	Rödby	Puttgården	April-19	Ferry	20	7,6		
	Puttgården	Hamburg	April-19	Coach	150	7		
	Hamburg	Köln	April-19	National Train	425	19,7		
	Köln	Brussels	April-19	National Train	220	10		
	Brussels	Paris	April-19	National Train	108	14,1		
	Paris	Paris	April-19	Local Subway	6	0,25		
	Paris	Hendaye	April-19	National Train	800	37,85		
	Hendaye	Lisbon	April-19	National Train	930	40		
	Lisbon	Merida	April-19	Coach	280	10		
	Merida	Madrid	April-19	National Train	340	19,4		
	Madrid	Barcelona	April-19	National Train	600	27,5		
	Barcelona	Lyon	April-19	National Train	600	17,5		
	Lyon	Brussels	April-19	National Train	730	33,8		
	Brussels	Copenhagen	April-19	Coach	930	30		
	Copenhagen	Lund	April-19	Electric train	60	0,5		
	Lund	Gothenburg	April-19	Coach	300	2,8		
					7019	**285,8**		**848,9**
STEPS PhD Summer School*	Gothenburg	Copenhagen	May-19	Coach	320	10		
	Copenhagen	Paris	May-19	Coach	1217	30		
	Paris	Paris	May-19	Local Subway	7			
	Paris	London	May-19	Eurostar	450	4,1		
	London	Brussels	May-19	Eurostar	375	5,8		
	Brussels	Copenhagen	May-19	Coach	1117	26		
	Copenhagen	Gothenburg	May-19	Coach	320	10		
					3806	**85,9**		**338**

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Summer bike trip, Austria	Gothenburg	Copenhagen	July-19	Electric train	340	3,4		95,2
	Copenhagen	Fredericia	July-19	Train	219	12.4		
	Fredericia	Hamburg	July-19	Train	300	17,4		
	Hamburg	Berlin	July-19	Train	285	12,8		
	Berlin	Praha	July-19	Train	280	7,6		
	Praha	Vienna	July-19	Train	402	18,1		85,3
	Vienna	Salzburg	July-19	National Train	312	14		180
	Salzburg	Stuttgart	July-19	National Train	440	19,8		
	Stuttgart	Hannover	July-19	Flixtrain	530	23,7		
	Hannover	Hamburg	July-19	Coach	150	8		
	Copenhagen	Gothenburg	July-19	Coach	317	17,1		
					4045	**167**		**360**
Visiting friends, Norwich, England	Gothenburg	Copenhagen	Oct-19	Electric train	340	3,4		360
	Copenhagen	Fredericia	Oct-19	Train	219	12.4		
	Fredericia	Hamburg	Oct-19	Train	300	17,4		
	Hamburg	Paris	Oct-19	Bus	800	22		
	Paris	London	Oct-19	Train	450	4,1		
	London	Norwich	Oct-19	Train	185	8		
	Norwich	London	Oct-19	Train	185	8		
	London	Paris	Oct-19	Train	450	4,1		
	Paris	Hamburg	Oct-19	Bus	800	22		
	Hamburg	Fredericia	Oct-19	Train	300	17,4		
	Fredericia	Copenhagen	Oct-19	Train	219	12.4		
	Copenhagen	Gothenburg	Oct-19	Electric train	340	3,4		
					4588	**109,8**		**360**
Christmas, Belfast, Northern Ireland	Gothenburg	Copenhagen	Dec-19	Electric train	340	3,4		377,4
	Copenhagen	Fredericia	Dec-19	Train	219	12.4		
	Fredericia	Hamburg	Dec-19	Train	300	17,4		
	Hamburg	Brussels	Dec-19	Bus	800	22		
	Brussels	London	Dec-19	Train	375	5,8		
					3835	**153,8**		**377,4**

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Home for Christmas, Belfast, Northern Ireland	London	Liverpool	Dec-19	Train	310	14		
	Liverpool	Belfast	Dec-19	Boat	233	34		
	Belfast	Liverpool	Dec-19	Boat	233	34		
	Liverpool	London	Dec-19	Train	310	14		
	London	Brussels	Dec-19	Train	375	5,8		
	Brussels	Copenhagen	Dec-19	Bus				
	Copenhagen	Gothenburg	Dec-19	Electric train	340	3,4		
					3835	**153,8**		**377,4**
Summer bike trip, Germany	Gothenburg	Lund	Aug-20	Train	300	3		272,8
	Lund	Trelleborg	Aug-20	Train	55	0,55		
	Trelleborg	Rostock	Aug-20	Boat	158	30		
	Rostock	Osnabrück	Aug-20	Train	450	20		
	Osnabrück	Bonn	Aug-20	Train	267	12		
	Bonn	Rostock	Aug-20	Train	710	32		
	Rostock	Trelleborg	Aug-20	Boat	158	30		
	Trelleborg	Lund	Aug-20	Train	55	0,55		
	Lund	Gothenburg	Aug-20	Train	300	3		
					2453	**131,1**		**272,8**
Christmas, Trondheim, Norway	Gothenburg	Oslo	Dec-20	Train	390	3,9		209
	Oslo	Trondheim	Dec-20	Train	545	5,5		
	Oslo	Gothenburg	Dec-20	Bus	390	21,6		
					1325	**31**		**209**

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Summer in Belfast	Gothenburg	Copenhagen	May-22	Train	360	3,3		377
	Copenhagen	Hamburg	May-22	Train	219	12.4		
	Hamburg	Brussels	May-22	Train	300	16		
	Brussels	London	June-22	Train	375	5,8		
	London	Cornwall	June-22	Electric car	431	4		
	Cornwall	London	June-22	Train	466	12		
	London	Liverpool	June-22	Train	310	8		
	Liverpool	Belfast	June-22	Boat	233	34		
	Belfast	Liverpool	July-22	Boat	233	34		
	Liverpool	London	July-22	Train	310	8		
	London	Dover	July-22	Train	375	5,8		
	Dover	Calais	July-22	Ferry	41	6		
	Calais	Hazebrouck	July-22	Train	61	1		
	Hazebrouck	Lille	July-22	Train	50	1		
	Lille	Ösnabruck	July-22	Bus	550	14		
	Ösnabruck	Hamburg	July-22	Train	240	6		
	Hamburg	Fredericia	July-22	Train	300	17,4		
	Fredericia	Copenhagen	July-22	Train	219	12.4		
	Copenhagen	Gothenburg	July-22	Coach	317	17,1		
	Gothenburg	Oslo	July-22	Train	390	3,9		
					5780	**197,3**		**377**
ESE Research Seminar*	Belfast	Liverpool	June-22	Ferry	233	34		264
	Liverpool	London	June-22	Train	310	14		
	London	Brussels	June-22	Train	375	5,8		
	Brussels	Ghent	June-22	Train	40	2,4		
	Brussels	London	June-22	Train	375	5,8		
	London	Liverpool	June-22	Train	310	14		
	Liverpool	Belfast	June-22	Ferry	233	34		
					1876	**110**		**264**

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Interrail trip	Hundarfossen	Oppdal	July-22	Train	218	2		114
	Oppdal	Oslo	July-22	Train	450	4		
	Oslo	Rygge	July-22	Bus	70	2		
	Rygge	Gothenburg	July-22	Train	326	2		
	Gothenburg	Malmo	July-22	Train	301	2		
	Malmo	Berlin	July-22	Train	840	16		
	Berlin	Dresden	July-22	Train	182	4		98
	Dresden	Schmilke	July-22	Train	50	1,3		
	Schmilke	Prague	July-22	Train	150	4		
	Prague	Brno	July-22	Train	189	5		
	Brno	Bratislava	July-22	Train	124	3		
	Bratislava	Ljubljana	July-22	Train	330	7		
	Ljubljana	Bohinjska Bistrica	Aug-22	Train	74	2		211
	Bohinjska Bistrica	Ljubljana	Aug-22	Train	74	2		
	Ljubljana	Erlangen	Aug-22	Train	509	12		
	Erlangen	Berlin	Aug-22	Train	452	11		
	Berlin	Rostock	Aug-22	Ferry	212	5		
	Rostock	Trelleborg	Aug-22	Train	158	30		
	Trelleborg	Malmo	Aug-22	Train	38	0,3		
	Malmo	Gothenburg	Aug-22	Train	301	2		
	Gothenburg	Rygge	Aug-22	Train	326	2		
	Rygge	Oslo	Aug-22	Bus	70	2		
					5444	**120,6**		**423**
Fall in Oslo, Norway	Oslo	Gothenburg	Aug-22	Train	390	3,9		
	Gothenburg	Oslo	Sep 22	Train	390	3,9		
	Oslo	Gothenburg	Sep 22	Train	390	3,9		
	Gothenburg	Oslo	Sep 22	Train	390	3,9		

Trip info	Trip start	Trip end	Date	Mode	Distance (km)	CO_2 (kg)	Flight CO_2 (kg)	Flight CO_2e (kg)
Fall in Oslo, Norway	Oslo	Gothenburg	Oct 22	Train	390	3,9		
	Gothenburg	Oslo	Oct 22	Train	390	3,9		
	Oslo	Gothenburg	Oct 22	Train	390	3,9		
	Gothenburg	Oslo	Nov 22	Train	390	3,9		
	Oslo	Gothenburg	Nov 22	Train	390	3,9		
	Gothenburg	Oslo	Nov 22	Train	390	3,9		
					3900	**39**		

	Distance (km)	Equivalent ($kgCO_2e$)	Emissions from flights ($kgCO_2$)	Flight equivalent $kgCO_2e$ (return)	Total Emissions ($kgCO_2$)
Total 2018	20484	192,1	2416	2416	2608,1
Total 2019 - 22	46572	1528,4	0	4098,6	1528,4
Total 2018 - 22	67056	1720,5	2416	6514	4136,5
Research-related*	15202	1190	545	2263,9	1190

References

Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C. D., Jager, N. W., & Lang, D. J. (2017). Leverage points for sustainability transformation. Ambio, 46(1), 30–39. https://doi.org/10.1007/s13280-016-0800-y

Achten, W. M., Almeida, J., & Muys, B. (2013). Carbon footprint of science: More than flying. Ecological indicators, 34, 352-355

Adelman, C, Kemmis, S. and Jenkins, D. (1980) Rethinking case study: notes from the second Cambridge conference. In H. Simon (ed.) Towards a Science of the Singular. Norwich: Centre for Applied Research in Education, University of East Anglia, pp. 45-61.

Ahlborg, H., & Nightingale, A. J. (2021). Chimeras of resource geographies: Unbounding ontologies and knowing nature. In *The Routledge Handbook of Critical Resource Geography* (pp. 22-33). Routledge.

Ahmed, S., 2014. Self-care as Warfare. Feminist Killjoys Blog. https://feministkilljoys.

Akkerman, S. F., Bakker, A., & Penuel, W. R. (2021). Relevance of Educational Research: An Ontological Conceptualization. *Educational Researcher*, *50*(6), 416–424. https://doi.org/10.3102/0013189X211028239

Alhadeff-Jones, M. (2017). Time and the rhythms of emancipatory education: Rethinking the temporal complexity of self and society (p. 238). Taylor & Francis.

Alonso-Yanez, G., House-Peters, L., Garcia-Cartagena, M., Bonelli, S., Lorenzo-Arana, I., & Ohira, M. (2019). Mobilizing transdisciplinary collaborations: Collective reflections on decentering academia in knowledge production. Global Sustainability, 2

Alves, J. (2015) "Unintentional Knowledge: What We Find When We're Not Looking." Chronicle of Higher Education 23 Jun. 2013. n.p. Web. 21 Feb. 2015. http://chronicle.com/article/Unintentional-Knowledge/139891/"

Alvesson, M. (2013). Do we have something to say? From re-search to roi-search and back again. Organization, 20(1), 79–90. https://doi.org/10.1177/1350508412460996

Alvesson, M., & Sandberg, J. (2013). Constructing research questions: Doing interesting research. Sage.

Alvesson, M., & Sköldberg, K. (2017). Reflexive methodology: New vistas for qualitative research. Sage.

Amsler, S., & Facer, K. (2017). Contesting anticipatory regimes in education: exploring alternative educational orientations to the future. *Futures*, *94*, 6-14.

Anderson, B. (2010). Preemption, precaution, preparedness: Anticipatory action and future geographies. *Progress in human geography*, *34*(6), 777-798.

Andersson, C., Törnberg, A., & Törnberg, P. (2014). Societal systems–complex or worse?. *Futures*, *63*, 145-157.

Andersson, J. (2018). The future of the world: Futurology, futurists, and the struggle for the post cold war imagination. Oxford University Press.

Andersson, S., & Rahe, U. (2017). Accelerate innovation towards sustainable living: exploring the potential of Living Labs in a recently completed case. *Journal of Design research*, *15*(3-4), 234-257.

Archer, M. S. (2007). Making our way through the world: Human reflexivity and social mobility. Cambridge University Press.

Archer, M. S. (Ed.). (2010). *Conversations about reflexivity* (p. 12). London: Routledge.

Ardoino, J. (1993). L'approche multiréférentielle (plurielle) des situations éducatives et formatives. Pratiques de Formation / Analyses, 25–26, 15–34.
Arendt, H., & Kohn, J. (2006). Between past and future. Penguin.
Armitage, D., Marschke, M., & Plummer, R. (2008). Adaptive co-management and the paradox of learning. *Global environmental change*, *18*(1), 86-98.
Avelino, F., & Grin, J. (2017). Beyond deconstruction. a reconstructive perspective on sustainability transition governance. Environmental Innovation and Societal Transitions, 22, 15-25.
Avelino, F., & Rotmans, J. (2009). Power in transition: an interdisciplinary framework to study power in relation to structural change. *European journal of social theory*, *12*(4), 543-569.
Avelino, F., Grin, J., Pel, B., & Jhagroe, S. (2016). The politics of sustainability transitions. Journal of Environmental Policy & Planning, 18(5), 557–567. https://doi.org/10.1080/1523908X.2016.1216782
Baedeker, C., Liedtke, C., & Welfens, M. J. (2017). Green economy as a framework for product-service systems development: The role of sustainable living labs. In Living Labs (pp. 35–52). Springer.
Bai, X., van der Leeuw, S., O'Brien, K., Berkhout, F., Biermann, F., Brondizio, E. S., Cudennec, C., Dearing, J., Duraiappah, A., Glaser, M., Revkin, A., Steffen, W., & Syvitski, J. (2016). Plausible and desirable futures in the Anthropocene: A new research agenda. Global Environmental Change, 39, 351–362. https://doi.org/10.1016/j.gloenvcha.2015.09.017
Baker, E., Crump, J., & Harris, P. (2019). Global Environment Outlook (GEO-6): Healthy Planet, Healthy People.
Bardwell, L.V. (1991). Problem-framing: a perspective on environmental problem-solving. Environ. Manage. 15, 603–612. https://doi.org/10.1007/BF02589620
Barnacle, R. (2005). Research education ontologies: Exploring doctoral becoming. Higher Education Research & Development, 24(2), 179–188. https://doi.org/10.1080/07294360500062995
Barnett, R. (2004). Learning for an unknown future. *Higher education Research & development*, *23*(3), 247-260.
Barry, A., & Born, G. (2013). Interdisciplinarity: Reconfigurations of the social and natural sciences. Routledge.
Barry, A., Born, G., & Weszkalnys, G. (2008). Logics of interdisciplinarity. Economy and society, 37(1), 20-49.
Bateson, N. (2021). The Era of Emergency Relocation: A Transcontextual Perspective. Journal of Constructivist Psychology, 34(1), 9-22.
Baxter, J., & Eyles, J. (1997). Evaluating qualitative research in social geography: Establishing 'rigour'in interview analysis. Transactions of the Institute of British Geographers, 22(4), 505–525.
Beck, U. (2016). The metamorphosis of the world: How climate change is transforming our concept of the world. John Wiley & Sons.
Beecroft, R. (2018). Embedding Higher Education into a Real-World Lab: A Process-Oriented Analysis of Six Transdisciplinary Project Courses. Sustainability, 10(10), 3798. https://doi.org/10.3390/su10103798
Benford, R. D., & Snow, D. A. (2000). Framing processes and social movements: An overview and assessment. *Annual review of sociology*, 611-639.
Bennett, E. M., Solan, M., Biggs, R., McPhearson, T., Norström, A. V., Olsson, P., Pereira, L., Peterson, G. D., Raudsepp-Hearne, C., Biermann, F., Carpenter, S. R., Ellis, E. C., Hichert, T., Galaz, V., Lahsen, M., Milkoreit, M., Martin López, B., Nicholas, K. A., Preiser, R., … Xu, J.

(2016). Bright spots: Seeds of a good Anthropocene. Frontiers in Ecology and the Environment, 14(8), 441–448. https://doi.org/10.1002/fee.1309
Bentz, J., O'Brien, K., & Scoville-Simonds, M. (2022). Beyond "blah blah blah": exploring the "how" of transformation. Sustainability Science, 17(2), 497-506.
Berg, B. L., & Lune, H. (2017). Qualitative research methods for the social sciences (Ninth edition). Pearson.
Berg, M., & Seeber, B. K. (2018). The slow professor. In The Slow Professor. University of Toronto Press.
Bessant, S. E. F., Robinson, Z. P., & Ormerod, R. M. (2015). Neoliberalism, new public management and the sustainable development agenda of higher education: History, contradictions and synergies. Environmental Education Research, 21(3), 417–432. https://doi.org/10.1080/13504622.2014.993933
Bhaskar, R. (2008). Dialectic: The pulse of freedom. Routledge.
Bhaskar, R. (2013). A realist theory of science. Routledge.
Bhaskar, R., & Hartwig, M. (2016). Enlightened common sense: The philosophy of critical realism. Routledge.
Bhaskar, R., Collier, A., Lawson, T., & Norrie, A. (1998). Critical realism. In Proceedings of the Standing Conference on Realism and Human Sciences, Bristol, UK (Vol. 4).
Billett, S. (2006). Constituting the workplace curriculum. Journal of curriculum studies, 38(1), 31-48.
Bjørkdahl, K., Duharte, F., & Santiago, A. (2022). Academic Flying and the Means of Communication.
Blythe, J., Silver, J., Evans, L., Armitage, D., Bennett, N. J., Moore, M. L., ... & Brown, K. (2018). The dark side of transformation: latent risks in contemporary sustainability discourse. *Antipode*, *50*(5), 1206-1223.
Blühdorn, I., & Welsh, I. (2007). Eco-politics beyond the paradigm of sustainability: A conceptual framework and research agenda. Environmental Politics, 16(2), 185–205. https://doi.org/10.1080/09644010701211650
Boggs, C. (1977). Marxism, prefigurative communism, and the problem of workers' control. Radical America, 11(6), 99-122.
Bonnett, A. (2003). Geography as the world discipline: Connecting popular and academic geographical imaginations. Area, 35(1), 55–63. https://doi.org/10.1111/1475-4762.00110
Borch, C. (2002). Interview with Edward W. Soja: Thirdspace, Postmetropolis, and Social Theory. Distinktion: Journal of Social Theory, 3(1), 113–120. https://doi.org/10.1080/1600910X.2002.9672816
Bosch, O. J., Nguyen, N. C., Maeno, T., & Yasui, T. (2013). Managing complex issues through evolutionary learning laboratories. *Systems Research and Behavioral Science*, *30*(2), 116-135.
Bosch-Ohlenschlager, S. J. M. van den. (2010). Transition experiments: Exploring societal changes towards sustainability. Erasmus Univ.
Boström, M., Andersson, E., Berg, M., Gustafsson, K., Gustavsson, E., Hysing, E., ... & Öhman, J. (2018). Conditions for transformative learning for sustainable development: A theoretical review and approach. *Sustainability*, *10*(12), 4479.
Boulton, J. G., Allen, P. M., & Bowman, C. (2015). *Embracing complexity: Strategic perspectives for an age of turbulence*. OUP Oxford.

Bradbury, H., Waddell, S., O' Brien, K., Apgar, M., Teehankee, B., & Fazey, I. (2019). A call to Action Research for Transformations: The times demand it. Action Research, 17(1), 3–10. https://doi.org/10.1177/1476750319829633

Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., Reinert, F., Abson, D. J., & von Wehrden, H. (2013). A review of transdisciplinary research in sustainability science. Ecological Economics, 92, 1–15. https://doi.org/10.1016/j.ecolecon.2013.04.008

Bregman, R. (2018). Utopia for realists. Bloomsbury Publishing.

Brenner, N. (2000). The Urban Question: Reflections on Henri Lefebvre, Urban Theory and the Politics of scale. International Journal of Urban and Regional Research, 24(2), 361–378. https://doi.org/10.1111/1468-2427.00234

Brown, H. S., Vergragt, P., Green, K., & Berchicci, L. (2003). Learning for Sustainability Transition through Bounded Socio-technical Experiments in Personal Mobility. Technology Analysis & Strategic Management, 15(3), 291–315. https://doi.org/10.1080/0953732031000160149 6

Brown, V. A., Harris, J. A., & Russell, J. Y. (Eds.). (2010). Tackling wicked problems through the transdisciplinary imagination. Earthscan.

Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: from classroom into the real world. *International Journal of Sustainability in Higher Education*.

Bryman, A. (2012). Social research methods (4th ed). Oxford University Press.

Buber, M. (2008). I and Thou. Howard Books.

Bulkeley, H., & Betsill, M. M. (2013). Revisiting the urban politics of climate change. Environmental Politics, 22(1), 136–154. https://doi.org/10.1080/09644016.2013.755797

Bulkeley, H., Coenen, L., Frantzeskaki, N., Hartmann, C., Kronsell, A., Mai, L., Marvin, S., McCormick, K., van Steenbergen, F., & Voytenko Palgan, Y. (2016). Urban living labs: Governing urban sustainability transitions. Current Opinion in Environmental Sustainability, 22, 13–17. https://doi.org/10.1016/j.cosust.2017.02.003

Bulten, E., Hessels, L. K., Hordijk, M., & Segrave, A. J. (2021). Conflicting roles of researchers in sustainability transitions: balancing action and reflection. Sustainability Science, 16(4), 1269-1283.

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martin-López, B., Hondrila, K., ... & Lang, D. J. (2021). A pluralistic and integrated approach to action-oriented knowledge for sustainability. Nature Sustainability, 4(2), 93-100.

Caniglia, G., Schäpke, N., Lang, D. J., Abson, D. J., Luederitz, C., Wiek, A., Laubichler, M. D., Gralla, F., & von Wehrden, H. (2017). Experiments and evidence in sustainability science: A typology. Journal of Cleaner Production, 169, 39–47. https://doi.org/10.1016/j.jclepro.2017.05.164

Caprotti, F., & Cowley, R. (2017). Interrogating urban experiments. Urban Geography, 38(9), 1441–1450. https://doi.org/10.1080/02723638.2016.1265870

Care, O., Bernstein, M. J., Chapman, M., Diaz Reviriego, I., Dressler, G., Felipe-Lucia, M. R., ... & Zähringer, J. G. (2021). Creating leadership collectives for sustainability transformations. Sustainability science, 16(2), 703-708. 8

Carlson, C. (2019). Students as Drivers of Change: Advancing Sustainability Science, confronting Society's Grand Challenges. Developing Change Agents.

Carton, W. (2019). "Fixing" climate change by mortgaging the future: negative emissions, spatiotemporal fixes, and the political economy of delay. *Antipode*, *51*(3), 750-769.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., Jäger, J., & Mitchell, R. B. (2003). Knowledge systems for sustainable development. Proceedings of the National Academy of Sciences, 100(14), 8086–8091.

Charli-Joseph, L., Siqueiros-Garcia, J. M., Eakin, H., Manuel-Navarrete, D., & Shelton, R. (2018). Promoting agency for social-ecological transformation: A transformation-lab in the Xochimilco social-ecological system. Ecology and Society, 23(2). https://doi.org/10.5751/ES-10214-230246

Charli-Joseph, L., Siqueiros-García, J. M., Eakin, H., Manuel-Navarrete, D., Mazari-Hiriart, M., Shelton, R., ... & Ruizpalacios, B. (2022). Enabling collective agency for sustainability transformations through reframing in the Xochimilco social–ecological system. Sustainability Science, 1-19.

Checkland, P. B. (1989). Soft systems methodology. Human systems management, 8(4), 273-289.

Checkland, P. (2000). Systems thinking, systems practice: includes a 30-year retrospective. *Journal-Operational Research Society*, *51*(5), 647-647.

Cheney, J., & Weston, A. (1999). Environmental ethics as environmental etiquette: Toward an ethics-based epistemology. Environmental Ethics, 21(2), 115-134.

Cherryholmes, C. (1988). Power and criticism: Poststructural investigations in education. New York: Teachers College Press.

Ciers, J., Mandic, A., Toth, L. D., & Op't Veld, G. (2018). Carbon footprint of academic air travel: A case study in Switzerland. Sustainability, 11(1), 80

Cilliers, P., & Preiser, R. (Eds.). (2010). *Complexity, difference and identity: An ethical perspective* (Vol. 26). Springer Science & Business Media.

Clark, A. M. (2016). Why Qualitative Research Needs More and Better Systematic Review. International Journal of Qualitative Methods, 15(1), 160940691667274. https://doi.org/10.1177/1609406916672741

Cockburn, J. (2022). Knowledge integration in transdisciplinary sustainability science: Tools from applied critical realism. Sustainable Development, 30(2), 358-374.

Coenen, L., Raven, R., & Verbong, G. (2010). Local niche experimentation in energy transitions: A theoretical and empirical exploration of proximity advantages and disadvantages. Technology in Society, 32(4), 295–302. https://doi.org/10.1016/j.techsoc.2010.10.006

Collins, B. (2020). "It's not talked about": The risk of failure in practice in sustainability experiments. Environmental Innovation and Societal Transitions, 35, 77–87. https://doi.org/10.1016/j.eist.2020.02.008

Collins, K., & Ison, R. (2009). Jumping off Arnstein's ladder: Social learning as a new policy paradigm for climate change adaptation. Environmental Policy and Governance, 19(6), 358–373. https://doi.org/10.1002/eet.523

Colyar, J. (2009). Becoming Writing, Becoming Writers. Qualitative Inquiry, 15(2), 421–436. https://doi.org/10.1177/1077800408318280

Cresswell, T. (2006). On the move: Mobility in the modern western world. New York: Routledge

Cresswell, T. (2014). Mobilities III: moving on. *Progress in Human Geography*, *38*(5), 712-721.

Daly, H. E. (1990). Toward some operational principles of sustainable development. Ecological Economics, 2(1), 1–6.

Danermark, B., Ekstrom, M., & Jakobsen, L. (2005). Explaining society: An introduction to critical realism in the social sciences. Routledge.

Davelaar, D. (2021). Transformation for sustainability: a deep leverage points approach. *Sustainability Science*, *16* (3), 727-747.
de Vries, B. J. M. (2019). Engaging with the Sustainable Development Goals by going beyond Modernity: An ethical evaluation within a worldview framework. Global Sustainability, 2. https://doi.org/10.1017/sus.2019.15
Dixon-Woods, M., Bonas, S., Booth, A., Jones, D. R., Miller, T., Sutton, A. J., Shaw, R. L., Smith, J. A., & Young, B. (2006). How can systematic reviews incorporate qualitative research? A critical perspective. Qualitative Research, 6(1), 27–44. https://doi.org/10.1177/1468794106058867
Douglas, A., Holmberg, J., Holmén, J., Williams, S., & Wise, E. (2021). Challenge Lab NMS Log Book: Exploring the role of hydrogen in realising a good life in North Middle Sweden through circular and low carbon industrial transformation. Region Gävleborg, Region Dalarna, Region Värmland.
Dreborg, K. H. (1996). Essence of backcasting. *Futures*, *28*(9), 813-828.
Dryzek, J. S. (2013). The politics of the earth: Environmental discourses (Third edition). Oxford University Press.
Duraiappah, A., van Atteveldt, N., Asah, S., Borst, G., Bugden, S., Buil, J. M., Ergas, O., Fraser, S., Mercier, J., Restrepo Mesa, J. F., Mizala, A., Mochizuki, Y., Okano, K., Piech, C., Pugh, K., Ramaswamy, R., Chatterjee Singh, N., & Vickers, E. (2021). The International Science and Evidence-based Education Assessment. Npj Science of Learning, 6(1), 7. https://doi.org/10.1038/s41539-021-00085-9
Eastman, J. R. (1897). The Relations Of Science And The Scientific Citizen To The General Government. Science, 5(118), 525–531. https://doi.org/10.1126/science.5.118.525
Egger, M., Smith, G. D., & O'Rourke, K. (2001). Introduction: Rationale, potentials, and promise of systematic reviews. Systematic Reviews in Health Care: Meta-Analysis in Context, 1–19.
Ehnert, F., Frantzeskaki, N., Barnes, J., Borgström, S., Gorissen, L., Kern, F., Strenchock, L., & Egermann, M. (2018). The Acceleration of Urban Sustainability Transitions: A Comparison of Brighton, Budapest, Dresden, Genk, and Stockholm. Sustainability, 10(3), 612. https://doi.org/10.3390/su10030612
Eisner, E. W. (1979). The use of qualitative forms of evaluation for improving educational practice. Educational Evaluation and Policy Analysis, 1(6), 11-19.
Elden, S. (2007). There is a politics of space because space is political: Henri Lefebvre and the production of space. Radical philosophy review, 10(2), 101-116.
Elzen, B., Geels, F. W., & Green, K. (Eds.). (2004). System innovation and the transition to sustainability: Theory, evidence and policy. Edward Elgar.
Emig, J. (1977). Writing as a Mode of Learning. College Composition and Communication, 28(2), 122. https://doi.org/10.2307/356095
Engeström, Y. (2015). *Learning by expanding*. Cambridge University Press.
Engle, R. A. (1987). Framing interactions to foster generative learning: A situative account of transfer in a community of learners classroom. Journal of the Learning Sciences, 15, 451–498.
Etherington, K. (2004). Becoming a reflexive researcher: Using our selves in research. Jessica Kingsley Publishers.
Evans, J. P. M., Karvonen, A., & Raven, R. (Eds.). (2016). The experimental city. Routledge, Taylor & Francis Group.
Evans, J., & Karvonen, A. (2014). 'Give Me a Laboratory and I Will Lower Your Carbon Footprint!' - Urban Laboratories and the Governance of Low-Carbon Futures:

Governance of low carbon futures in Manchester. International Journal of Urban and Regional Research, 38(2), 413–430. https://doi.org/10.1111/1468-2427.12077
Facer, K. (2013). The problem of the future and the possibilities of the present in education research. *International Journal of Educational Research*, *61*, 135-143.
Facer, K. (2022). Imagination and the Future University. *Critical Times*, *5*(1), 202–216. https://doi.org/10.1215/26410478-9536559
Fam, D., Clarke, E., Freeth, R., Derwort, P., Klaniecki, K., Kater-Wettstädt, L., ... & Horcea-Milcu, A. I. (2020). Interdisciplinary and transdisciplinary research and practice: balancing expectations of the 'old'academy with the future model of universities as 'problem solvers'. *Higher Education Quarterly*, *74*(1), 19-34.universities as "Problem Solvers." Higher Education Quarterly 74: 19–34.
Fazey, I., Schäpke, N., Caniglia, G., Patterson, J., Hultman, J., van Mierlo, B., Säwe, F., Wiek, A., Wittmayer, J., Aldunce, P., Al Waer, H., Battacharya, N., Bradbury, H., Carmen, E., Colvin, J., Cvitanovic, C., D'Souza, M., Gopel, M., Goldstein, B., … Wyborn, C. (2018). Ten essentials for action-oriented and second order energy transitions, transformations and climate change research. Energy Research & Social Science, 40, 54–70. https://doi.org/10.1016/j.erss.2017.11.026
Feola, G. (2015). Societal transformation in response to global environmental change: A review of emerging concepts. Ambio, 44(5), 376–390. https://doi.org/10.1007/s13280-014-0582-z
Feola, G., 2020. Capitalism in sustainability transitions research–Time for a critical turn? Environ. Innov. Soc. Transit. 35, 241–250.
Fischer, L.-B., & Newig, J. (2016). Importance of Actors and Agency in Sustainability Transitions: A Systematic Exploration of the Literature. Sustainability, 8(5), 476. https://doi.org/10.3390/su8050476
Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and society*, *15*(4).
Flyvbjerg, B. (2006). Five misunderstandings about case-study research. Qualitative inquiry, 12(2), 219-245.
Foucault, M. (1977) A Preface to Transgression, in: D. F. Bouchard (ed. and trans.), *Language, Counter-Memory, Practice: Selected Essays and Interviews* (Ithaca, NY, Cornell University Press), pp. 29– 52.
Frantzeskaki, N. (2018). Co creating sustainable urban futures. Springer Berlin Heidelberg.
Frantzeskaki, N., van Steenbergen, F., & Stedman, R. C. (2018). Sense of place and experimentation in urban sustainability transitions: The Resilience Lab in Carnisse, Rotterdam, The Netherlands. Sustainability Science, 13(4), 1045–1059. https://doi.org/10.1007/s11625-018-0562-5
Freeth, R., & Caniglia, G. (2020). Learning to collaborate while collaborating: advancing interdisciplinary sustainability research. *Sustainability science*, *15*(1), 247-261.
Friere, P. (1970). Pedagogy of the oppressed.
Freire, P. (2000a). Pedagogy of freedom: Ethics, democracy, and civic courage. Rowman & Littlefield Publishers.
Frick, B. (2010). Creativity in doctoral education: Conceptualising the original contribution.
Fuller, T., & Loogma, K. (2009). Constructing futures: A social constructionist perspective on foresight methodology. *Futures*, *41*(2), 71-79.
Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. Futures, 25(7), 739–755.

Gamble JA (2008) A developmental evaluation primer. JW McConnell Family Foundation Montreal
Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. Research Policy, 31(8–9), 1257–1274.
Geels, F.W. (2005). Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. Technological Forecasting and Social Change, 72(6), 681–696. https://doi.org/10.1016/j.techfore.2004.08.014
Geels, F. W. (2010). Ontologies, socio-technical transitions (to sustainability), and the multi-level perspective. Research Policy, 39(4), 495–510. https://doi.org/10.1016/j.respol.2010.01.022
Gibbons, M. (2000). Mode 2 society and the emergence of context-sensitive science. Science and Public Policy, 27(3), 159–163. https://doi.org/10.3152/147154300781782011
Gieryn, T. F. (2006). City as Truth-Spot: Laboratories and Field-Sites in Urban Studies. Social Studies of Science, 36(1), 5–38. https://doi.org/10.1177/0306312705054526
Glover, A., Lewis, T., & Strengers, Y. (2022). The Absent Presence of Aeromobility: A Case of Australian Academic Air Travel Practices and University Policy. In *Academic Flying and the Means of Communication* (pp. 79-101). Palgrave Macmillan, Singapore.
Gram-Hanssen, I., Schafenacker, N., & Bentz, J. (2022). Decolonizing transformations through 'right relations'. *Sustainability Science*, *17*(2), 673-685.
Grant, M. J., & Booth, A. (2009). A typology of reviews: An analysis of 14 review types and associated methodologies: A typology of reviews, Maria J. Grant & Andrew Booth. Health Information & Libraries Journal, 26(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x
Gras, D., Conger, M., Jenkins, A., & Gras, M. (2020). Wicked problems, reductive tendency, and the formation of (non-) opportunity beliefs. Journal of Business Venturing, 35(3).
Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P., Kyriakidou, O., & Peacock, R. (2005). Storylines of research in diffusion of innovation: A meta-narrative approach to systematic review. Social Science & Medicine, 61(2), 417–430.
Grin, J. (2020). 'Doing'system innovations from within the heart of the regime. *Journal of Environmental Policy & Planning*, *22*(5), 682-694.
Grin, J., Rotmans, J., & Schot, J. W. (2010). Transitions to sustainable development: New directions in the study of long term transformative change. Routledge.
Guggenheim, M. (2012). Laboratizing and de-laboratizing the world: Changing sociological concepts for places of knowledge production. History of the Human Sciences, 25(1), 99–118. https://doi.org/10.1177/0952695111422978
Gustafsson, K., & Hagström, L. (2018). what is the point? Teaching graduate students how to construct political science research puzzles. European Political Science, 17(4), 634–648. https://doi.org/10.1057/s41304-017-0130-y
Günther, G. (1962). *Cybernetic ontology and transjunctional operations*. Electrical Engineering Research Laboratory, University of Illinois.
Haider, L. J., Hentati-Sundberg, J., Giusti, M., Goodness, J., Hamann, M., Masterson, V. A., Meacham, M., Merrie, A., Ospina, D., Schill, C., & Sinare, H. (2018). The undisciplinary journey: Early-career perspectives in sustainability science. Sustainability Science, 13(1), 191–204. https://doi.org/10.1007/s11625-017-0445-1
Hansen, T., & Coenen, L. (2015). The geography of sustainability transitions: Review, synthesis and reflections on an emergent research field. Environmental Innovation and Societal Transitions, 17, 92–109. https://doi.org/10.1016/j.eist.2014.11.001

Hargreaves, T., Longhurst, N., & Seyfang, G. (2013). Up, Down, round and round: Connecting Regimes and Practices in Innovation for Sustainability. Environment and Planning A, 45(2), 402–420. https://doi.org/10.1068/a45124
Hebinck, A., Vervoort, J. M., Hebinck, P., Rutting, L., & Galli, F. (2018). Imagining transformative futures: participatory foresight for food systems change.
Hebinck, A., Diercks, G., von Wirth, T., Beers, P. J., Barsties, L., Buchel, S., ... & Loorbach, D. (2022). An actionable understanding of societal transitions: the X-curve framework. *Sustainability science*, *17*(3), 1009-1021.
Hector, P. (2018). Making and repairing places for making and repairing. Strategic Design Research Journal, 11(2). https://doi.org/10.4013/sdrj.2018.112.07
Holden, P., Cockburn, J., Shackleton, S., & Rosenberg, E. (2019). Supporting and developing competencies for transdisciplinary postgraduate research: a PhD scholar perspective. Developing Change Agents.
Holdsworth, S., Thomas, I., & Hegarty, K. (2013). Sustainability education: Theory and practice. In *International handbook of research on environmental education* (pp. 349-358). Routledge.
Holling, C. S., & Gunderson, L. H. (2002). Resilience and adaptive cycles. *In: Panarchy: Understanding Transformations in Human and Natural Systems, 25-62*.
Holmberg, J. (2014). 4. Transformative learning and leadership for a sustainable future: Challenge Lab at Chalmers University of Technology. In P. B. Corcoran, B. P. Hollingshead, H. Lotz-Sisitka, A. E. J. Wals, & J. P. Weakland (Eds.), Intergenerational learning and transformative leadership for sustainable futures (pp. 91–102). Wageningen Academic Publishers. https://doi.org/10.3920/978-90-8686-802-5_4
Holmberg, J., & Larsson, J. (2018). A sustainability lighthouse—Supporting transition leadership and conversations on desirable futures. Sustainability, 10(11), 3842.
Holmberg, J., & Robèrt, K. H. (2000). Backcasting—A framework for strategic planning. *International Journal of Sustainable Development & World Ecology*, *7*(4), 291-308.
Holmén, J., Adawi, T., & Holmberg, J. (2021). Student-led sustainability transformations: employing realist evaluation to open the black box of learning in a Challenge Lab curriculum. *International Journal of Sustainability in Higher Education*.
Holmén, J., & Holmberg, J. (2022). /Thinking beyond, broad and together: Exploring features of guiding principles for sustainability in navigating transformations/ [Manuscript]
Hölscher, K., Wittmayer, J. M., & Loorbach, D. (2018). Transition versus transformation: What's the difference?. Environmental innovation and societal transitions, 27, 1-3.
Hölscher, K., Wittmayer, J. M., Hirschnitz-Garbers, M., Olfert, A., Walther, J., Schiller, G., & Brunnow, B. (2021). Transforming science and society? Methodological lessons from and for transformation research. *Research Evaluation*, *30*(1), 73-89.
Hooghe, L., & Marks, G. (2003). Unraveling the central state, but how? Types of multi-level governance. American Political Science Review, 97(2), 233–243.
Hooks, B. (1994). *Teaching to transgress*. Routledge.
Hooks, B. (2013). *Teaching community: A pedagogy of hope*. Routledge.
Hopwood, B., Mellor, M., & O'Brien, G. (2005). Sustainable development: Mapping different approaches. Sustainable Development, 13(1), 38–52. https://doi.org/10.1002/sd.244
Horcea-Milcu, A. I., Leventon, J., & Lang, D. J. (2022). Making transdisciplinarity happen: Phase 0, or before the beginning. Environmental Science & Policy, 136, 187-197.

Hossain, M., Leminen, S., & Westerlund, M. (2019). A systematic review of living lab literature. Journal of Cleaner Production, 213, 976–988. https://doi.org/10.1016/j.jclepro.2018.12.257
Hulme, M. (2011). Reducing the Future to Climate: A Story of Climate Determinism and Reductionism. Osiris, 26(1), 245–266. https://doi.org/10.1086/661274
Hume, A., & Coll, R. (2010). Authentic student inquiry: The mismatch between the intended curriculum and the student-experienced curriculum. Research in Science & Technological Education, 28(1), 43-62.
Irwin, T. (2015). Transition design: A proposal for a new area of design practice, study, and research. *Design and Culture*, *7*(2), 229-246.
Ishihara, S., Tommasini, A., Ponzelar, C., & Livmar, E. (2021). "Student-led education for a better world?" Reflections in conversation. Högre utbildning, 11(3).
Ison, R. (2010). Systems practice: how to act in a climate change world (pp. I-XVI). London: Springer.
Iuel-Stissing, J., Pallesen, T., Karnøe, P., & Jacobsen, P. H. (2020). Governing system transitions in the context of scattered agency: Flexibility, action, and ecologies of epistemic equipment. Energy Research & Social Science, 69, 101730. https://doi.org/10.1016/j.erss.2020.101730
Jackson, M. C. (2016). Systems thinking: Creative holism for managers. John Wiley & Sons, Inc..
Jacobs, M. (1999). Sustainable development as a contested concept. In 'Fairness and Futurity: Essays on Environmental Sustainability and Social Justice'. (Ed. M. Dobson.) Oxford Scholarship Online. Oxford: Oxford University Press.
Jasanoff, S. (2018). Just transitions: A humble approach to global energy futures. *Energy Research & Social Science*, *35*, 11-14.
Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E., Hickler, T., Hornborg, A., Kronsell, A., Lövbrand, E., & Persson, J. (2011). Structuring sustainability science. Sustainability Science, 6(1), 69–82. https://doi.org/10.1007/s11625-010-0117-x
Jickling, B., Lotz-Sisitka, H., Olvitt, L., O'Donoghue, R., Schudel, I., McGarry, D., & Niblett, B. (2021). *Environmental Ethics: A Sourcebook for Educators*. African Sun Media.
Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. Journal of Mixed Methods Research, 1(2), 112–133. https://doi.org/10.1177/1558689806298224
Kagan, S. (2019). Artful Sustainability in Transdisciplinary Spaces of Possibilities. Transdisciplinary Journal of Engineering and Science, 10(1). https://doi.org/10.22545/2019/0117
Kates, R. W. (2011). What kind of a science is sustainability science? Proceedings of the National Academy of Sciences, 108(49), 19449–19450. https://doi.org/10.1073/pnas.1116097108
Keefer, J. M. (2015). Experiencing doctoral liminality as a conceptual threshold and how supervisors can use it. *Innovations in Education and Teaching International*, *52*(1), 17-28.
Kemp, R., Loorbach, D., & Rotmans, J. (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. *The International Journal of Sustainable Development & World Ecology*, *14*(1), 78-91.
Khazem, D. (2018). Critical realist approaches to global learning: A focus on education for sustainability. *International Journal of Development Education and Global Learning*.

Kiriakos, C. M., & Tienari, J. (2018). Academic writing as love. Management Learning, 49(3), 263–277. https://doi.org/10.1177/1350507617753560

Kivimaa, P., Hildén, M., Huitema, D., Jordan, A., & Newig, J. (2017). Experiments in climate governance – A systematic review of research on energy and built environment transitions. Journal of Cleaner Production, 169, 17–29. https://doi.org/10.1016/j.jclepro.2017.01.027

Kivimaa, P., Boon, W., Hyysalo, S., & Klerkx, L. (2018). Towards a typology of intermediaries in sustainability transitions: A systematic review and a research agenda. Research Policy. https://doi.org/10.1016/j.respol.2018.10.006

Klinenberg, E. (2015). Heat wave: A social autopsy of disaster in Chicago. University of Chicago Press.

Kluge, S. (2000). Empirically Grounded Construction of Types and Typologies in Qualitative Social Research. Orum: Qualitative Social Research, 1(1), 11.

Knorr-Cetina, K. D. (1981). The micro-sociological challenge of macro-sociology: Towards a reconstruction of social theory and methodology.

Knorr-Cetina, K. (1992). The couch, the cathedral, and the laboratory: On the relationship between experiment and laboratory in science. 14.

Knox, H. (2022). Not Flying as Anticipatory Critique. The Professional Geographer, 74(1), 162-164. ers for a sustainable future

Kok, K. P. W. (2022). Turning the tide: Governance and politics of transdisciplinary experimentation for sustainability transitions.

Köhler, J., Geels, F. W., Kern, F., Markard, J., Onsongo, E., Wieczorek, A., Alkemade, F., Avelino, F., Bergek, A., Boons, F., Fünfschilling, L., Hess, D., Holtz, G., Hyysalo, S., Jenkins, K., Kivimaa, P., Martiskainen, M., McMeekin, A., Mühlemeier, M. S., … Wells, P. (2019). An agenda for sustainability transitions research: State of the art and future directions. Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2019.01.004

Kohler, R. E. (2002). Labscapes: Naturalizing the Lab. History of Science, 40(4), 473–501. https://doi.org/10.1177/007327530204000405

Kreil, A. (2022) Reducing the climate impact associated with air travel: Shifting perspectives within and beyond Academia Doctoral Thesis: https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/519412/DissertationAgnesS.Kreil.pdf?sequence=1&isAllowed=y

Kuntz, A. M., & Petrovic, J. E. (2018). (Un) fixing education. Studies in philosophy and education, 37(1), 65-80.

Lam, D. P., Martín-López, B., Wiek, A., Bennett, E. M., Frantzeskaki, N., Horcea-Milcu, A. I., & Lang, D. J. (2020). Scaling the impact of sustainability initiatives: a typology of amplification processes. Urban Transformations, 2(1), 1-24.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. Sustainability Science, 7(S1), 25–43. https://doi.org/10.1007/s11625-011-0149-x

Lange, E. A., O'Neil, J. K. P., & Ross, K. E. (2021). Educating during the great transformation: relationality and transformative sustainability education. *Andragoška spoznanja*, *27*(1), 23-46.

Larsson, J., & Holmberg, J. (2018). Learning while creating value for sustainability transitions: The case of Challenge Lab at Chalmers University of Technology. Journal of Cleaner Production, 172, 4411–4420. https://doi.org/10.1016/j.jclepro.2017.03.072

Latour, B. (1983). Give me a Laboratory and I will raise the world. In K. Knorr-Cetina and M. Mulkay (Eds.), Science Observed: Perspectives on the Social Study of Science, Sage Publications, London., 32.
Latour, B. (1999). Pandora's hope: Essays on the reality of science studies. Harvard University Press.
Latour, B. (2018). Down to earth: Politics in the new climatic regime. John Wiley & Sons.
Latour, B., & Woolgar, S. (2013). Laboratory life: The construction of scientific facts. Princeton University Press.
Lawhon, M., & Murphy, J. T. (2012). Socio-technical regimes and sustainability transitions: Insights from political ecology. Progress in Human Geography, 36(3), 354–378. https://doi.org/10.1177/0309132511427960
Lazurko, A., Alamenciak, T., Hill, L. S., Muhl, E.-K., Osei, A. K., Pomezanski, D., Schang, K., & Sharmin, D. F. (2020). What Will a PhD Look Like in the Future? Perspectives on Emerging Trends in Sustainability Doctoral Programs in a Time of Disruption. *World Futures Review*, *12*(4), 369–384. https://doi.org/10.1177/1946756720976710
Leach, M., Stirling, A. C., & Scoones, I. (2010). Dynamic sustainabilities: technology, environment, social justice (p. 232). Taylor & Francis.
Leander, K. M., Phillips, N. C., & Taylor, K. H. (2010). The Changing Social Spaces of Learning: Mapping New Mobilities. Review of Research in Education, 34(1), 329–394. https://doi.org/10.3102/0091732X09358129
Lee, C.-K., Lee, J., Lo, P.-W., Tang, H.-L., Hsiao, W.-H., Liu, J.-Y., & Lin, T.-L. (2011). Taiwan Perspective: Developing Smart Living Technology. International Journal of Automation and Smart Technology, 1(1), 93–106. https://doi.org/10.5875/ausmt.v1i1.74
Lefebvre, H., & Nicholson-Smith, D. (1991). The production of space (Vol. 142). Oxford Blackwell.
Leonard, L. (2010). Negotiating Authorship for Doctoral Dissertation Publications: A Reply. Qualitative Health Research, 20(5), 723–726. https://doi.org/10.1177/1049732310367642
Lewin, K.; 1946. Action research and minority problems. Journal of Social Issues, 2(4), 34-46.
Lin, L., & Cranton, P. (2005). From scholarship student to responsible scholar: A transformative process. Teaching in Higher Education, 10(4), 447–459. https://doi.org/10.1080/13562510500239026
Lindstrom, T., Vakilizadeh, F., & Middlecamp, C. H. (2015). Light Bulbs: A Bright Idea for Teaching and Learning Sustainability. Sustainability: The Journal of Record, 8(2), 61–69. https://doi.org/10.1089/SUS.2015.0020
Livingstone, D. N. (2003). Putting science in its place: Geographies of scientific knowledge. University of Chicago Press.
Livingstone, D. N. (2007). Science, site and speech: Scientific knowledge and the spaces of rhetoric. History of the Human Sciences, 20(2), 71–98. https://doi.org/10.1177/0952695107076516
Lipari, L. (2015). *Listening, thinking, being: Toward an ethics of attunement*. Penn State Press.
Longhurst, N. (2015). Towards an 'alternative'geography of innovation: Alternative milieu, socio-cognitive protection and sustainability experimentation. Environmental Innovation and Societal Transitions, 17, 183–198.
Lönngren, J., Ingerman, Å., & Svanström, M. (2017). Avoid, control, succumb, or balance: Engineering students' approaches to a wicked sustainability problem. *Research in Science Education*, *47*(4), 805-831.

Lönngren, J., & Van Poeck, K. (2021). Wicked problems: A mapping review of the literature. International Journal of Sustainable Development & World Ecology, 28(6), 481-502.
Loorbach, D. (2007). Transition management: New mode of governance for sustainable development = Transitiemanagement ; nieuwe vorm van governance voor duurzame ontwikkeling. Internat. Books.
Loorbach, D. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. Governance, 23(1), 161–183.
Loorbach, D. A. (2022). Designing radical transitions: a plea for a new governance culture to empower deep transformative change. City, Territory and Architecture, 9(1), 1-11.
Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability transitions research: transforming science and practice for societal change. Annual Review of Environment and Resources, 42(1), 599-626.
Loorbach, D., Wittmayer, J., Avelino, F., von Wirth, T., & Frantzeskaki, N. (2020). Transformative innovation and translocal diffusion. Environmental Innovation and Societal Transitions, 35, 251–260.
Loring, P. A. (2020). Threshold concepts and sustainability: Features of a contested paradigm. FACETS, 5(1), 182–199. https://doi.org/10.1139/facets-2019-0037
Lotz-Sisitka, H., Wals, A. E., Kronlid, D., & McGarry, D. (2015). Transformative, transgressive social learning: Rethinking higher education pedagogy in times of systemic global dysfunction. Current Opinion in Environmental Sustainability, 16, 73–80. https://doi.org/10.1016/j.cosust.2015.07.018
Lotz-Sisitka, H., Ali, M. B., Mphepo, G., Chaves, M., Macintyre, T., Pesanayi, T., Wals, A., Mukute, M., Kronlid, D., Tran, D. T., Joon, D., & McGarry, D. (2016). Co-designing research on transgressive learning in times of climate change. *Current Opinion in Environmental Sustainability*, *20*, 50–55. https://doi.org/10.1016/j.cosust.2016.04.004
Lovitts, B. E. (2005). Being a good course-taker is not enough: A theoretical perspective on the transition to independent research. Studies in Higher Education, 30(2), 137–154. https://doi.org/10.1080/03075070500043093
Luederitz, C., Schäpke, N., Wiek, A., Lang, D. J., Bergmann, M., Bos, J. J., ... & Westley, F. R. (2017). Learning through evaluation–A tentative evaluative scheme for sustainability transition experiments. *Journal of Cleaner Production*, *169*, 61-76.
Lumosi, C. K., Pahl-Wostl, C., & Scholz, G. (2019). Can 'learning spaces' shape transboundary management processes? Evaluating emergent social learning processes in the Zambezi basin. *Environmental science & policy*, *97*, 67-77.
Lund, C. (2014). Of what is this a case?: Analytical movements in qualitative social science research. *Human organization*, *73*(3), 224-234.
Lyall, C. (2019). Being an interdisciplinary academic: How institutions shape university careers. Springer.
Lynch, M. (1985). Art and artifact in laboratory science. A Study of Shop Work and Shop Talk in a Research Laboratory.
Macura, B., Suškevičs, M., Garside, R., Hannes, K., Rees, R., & Rodela, R. (2019). Systematic reviews of qualitative evidence for environmental policy and management: An overview of different methodological options. Environmental Evidence, 8(1). https://doi.org/10.1186/s13750-019-0168-0
Maeckelbergh, M. (2011). Doing is believing: Prefiguration as strategic practice in the alterglobalizationmovement.Social Movement Studies,10(1), 1–20.

Marchal, B., Westhorp, G., Wong, G., Van Belle, S., Greenhalgh, T., Kegels, G., & Pawson, R. (2013). Realist RCTs of complex interventions–an oxymoron. Social Science & Medicine, 94, 124-128.
Marinetto, M. (2007). Social theory, the State and modern society. McGraw-Hill Education (UK).
Markard, J., Geels, F. W., & Raven, R. (2020). Challenges in the acceleration of sustainability transitions. Environmental Research Letters. https://doi.org/10.1088/1748-9326/ab9468
Marshall, J. (1999). Living life as inquiry. *Systemic practice and action research*, *12*(2), 155-171.
Mason, S., & Merga, M. (2018). Integrating publications in the social science doctoral thesis by publication. Higher Education Research & Development, 37(7), 1454–1471. https://doi.org/10.1080/07294360.2018.1498461
Massumi, B. (2007). Potential politics and the primacy of preemption. Theory & Event, 10(2).
Mattioli, G., Roberts, C., Steinberger, J. K., & Brown, A. (2020). The political economy of car dependence: A systems of provision approach. *Energy Research & Social Science*, *66*, 101486.
Max-Neef, M., Elizalde, A., & Hopenhyan, M. (1989). Human Scale Development: Development Dialogue. Dag Hammarskjold.
McClintock, D., Ison, R., & Armson, R. (2003). Metaphors for reflecting on research practice: researching with people. Journal of Environmental Planning and Management, 46(5), 715-731.
McCrory, G. (2016). Learning hard or hardly learning?: Exploring processes of experiential, transformative and social learning in an urban living lab. Master Thesis Series in Environmental Studies and Sustainability Science.
McCrory, G., Schäpke, N., Holmén, J., & Holmberg, J. (2020). Sustainability-oriented labs in real-world contexts: An exploratory review. Journal of Cleaner Production, 277, 123202. https://doi.org/10.1016/j.jclepro.2020.123202
McGibbon, C., Ophoff, J., & Van Belle, J.-P. (2014). Our building is smarter than your building: The use of competitive rivalry to reduce energy consumption and linked carbon footprint. Knowledge Management & E-Learning: An International Journal, 6(4), 464–471.
McLellan, B. C., Chapman, A. J., & Aoki, K. (2016). Geography, urbanization and lock-in – considerations for sustainable transitions to decentralized energy systems. Journal of Cleaner Production, 128, 77–96. https://doi.org/10.1016/j.jclepro.2015.12.092
Meadowcroft, J. (2009). What about the politics? Sustainable development, transition management, and long term energy transitions. Policy Sciences, 42(4), 323–340. https://doi.org/10.1007/s11077-009-9097-z
Meadowcroft, J. (2011). Engaging with the politics of sustainability transitions. Environmental Innovation and Societal Transitions, 1(1), 70–75. https://doi.org/10.1016/j.eist.2011.02.003
Meadows, D. H. (2008). Thinking in systems: A primer. chelsea green publishing.
Menny, M., Palgan, Y. V., & McCormick, K. (2018). Urban Living Labs and the Role of Users in Co-Creation. GAIA - Ecological Perspectives for Science and Society, 27(1), 68–77. https://doi.org/10.14512/gaia.27.S1.14
Merriam, S. B. (1988). Case study research in education: A qualitative approach. Jossey-Bass.

Merrifield, A. (1999). The Extraordinary Voyages of Ed Soja: Inside the "Trialectics of Spatiality". Annals of the Association of American Geographers, 89(2), 345–347. https://doi.org/10.1111/0004-5608.00151
Midgley, G. (2000). Systemic intervention. In Systemic intervention (pp. 113-133). Springer, Boston, MA.
Midgley, G. (2003). Science As Systemic Intervention: Some Implications Of Systems Thinking And Complexity For The Philosophy Of Science. 24.
Midgley, M. (2003). The myths we live by. Taylor & Francis.
Miller, T. R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2014). The future of sustainability science: A solutions-oriented research agenda. Sustainability Science, 9(2), 239–246. https://doi.org/10.1007/s11625-013-0224-6
Miller, R. L., & Campbell, R. (2006). Taking stock of empowerment evaluation: An empirical review. *American Journal of Evaluation*, *27*(3), 296-319.
Mingers, J. (2014). Systems thinking, critical realism and philosophy: A confluence of ideas. Routledge.
Mitchell, C., & Willetts, J. (2009). Quality criteria for inter-and trans-disciplinary doctoral research outcomes. *Prepared for ALTC Fellowship: Zen and the Art of Transdisciplinary Postgraduate Studies. Sydney, Australia: Institute for Sustainable Futures, University of Technology, Sydney*.
Mitchell, C., Cordell, D., & Fam, D. (2015). Beginning at the end: The outcome spaces framework to guide purposive transdisciplinary research. *Futures*, *65*, 86-96.
Moriggi, A., Soini, K., Franklin, A., & Roep, D. (2020). A care-based approach to transformative change: ethically-informed practices, relational response-ability & emotional awareness. Ethics, Policy & Environment, 23(3), 281-298.
Morin, E. (2008). On complexity (S.M. Kelly, Trans.). Cresskill, NJ: Hampton Press. (Original work published 1990)
Moser, S. C., & Fazey, I. (2021). If it is life we want: a prayer for the future (of the) University. *Frontiers in Sustainability*, *2*, 662657.
Mukute, M., Mudokwani, K., McAllister, G., & Nyikahadzoi, K. (2018). Exploring the potential of developmental work research and change laboratory to support sustainability transformations: a case study of organic agriculture in Zimbabwe. *Mind, Culture, and Activity*, *25*(3), 229-246.
Murphy, J. T. (2015). Human geography and socio-technical transition studies: Promising intersections. Environmental Innovation and Societal Transitions, 17, 73–91. https://doi.org/10.1016/j.eist.2015.03.002
Nandy, A. (1996). The politics of indigenous knowledge and contending ideals of the university. In R. Hayhoe & J. Pan (Eds.), East-West dialogue in knowledge and higher education (pp. 296307). At-monk, NY: M. E. Sharpe.
Ness, B. (2020). Approaches for Framing Sustainability Challenges: Experiences from Swedish Sustainability Science Education. In T. Mino & S. Kudo (Eds.), Framing in Sustainability Science (pp. 35–53). Springer Singapore. https://doi.org/10.1007/978-981-13-9061-6_3
Ness, B., & Wahl, D. (2022). Getting personal with collaborative sustainability experimentation: Reflections and recommendations from a transdisciplinary partnership with the Swedish craft beer sector. *Ambio*, *51*(12), 2544-2556.
Nevens, F., Frantzeskaki, N., Gorissen, L., & Loorbach, D. (2013). Urban Transition Labs: Co-creating transformative action for sustainable cities. Journal of Cleaner Production, 50, 111–122. https://doi.org/10.1016/j.jclepro.2012.12.001

Nevens, F., & Roorda, C. (2014). A climate of change: A transition approach for climate neutrality in the city of Ghent (Belgium). *Sustainable Cities and Society*, *10*, 112-121.
Nicholas, K. (2021). Under the sky we make: How to be human in a warming world. GP Putnam's Sons.
O'Brien K (2021) You matter more than you think: quantum social change for a thriving world. (forthcoming), cCHANGE Press, Oslo
O'Brien, K., & Sygna, L. (2013). Responding to climate change: the three spheres of transformation. *Proceedings of transformation in a changing climate*, *16*, 23.
O'Donoghue, R. (2014). Think piece: Re-thinking education for sustainable development as transgressive processes of educational engagement with human conduct, emerging matters of concern and the common good. *Southern African Journal of Environmental Education*, *30*, 7-26.
O'Riordan, T., & Voisey, H. (1997). The political economy of sustainable development. Environmental Politics, 6(1), 1–23. https://doi.org/10.1080/09644019708414309
Olsson P, Galaz V, Boonstra WJ. 2014. Sustainability transformations: a resilience perspective. Ecol. Soc. 19:1
Olsson, L., & Jerneck, A. (2018). Social fields and natural systems: Integrating knowledge about society and nature. Ecology and Society, 23(3). https://doi.org/10.5751/ES-10333-230326
Olsson, L., Jerneck, A., Thoren, H., Persson, J., & O'Byrne, D. (2015). Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use of resilience. Science Advances, 1(4), e1400217. https://doi.org/10.1126/sciadv.1400217
Opitz, D. L., Bergwik, S., & Van Tiggelen, B. (2016). Domesticity in the making of modern science. Springer.
Palmer, P. J. (1998) The courage to teach: Exploring the inner landscape of a teacher's life. John Wiley & Sons.
Patomäki, H. (2006). Realist Ontology for Futures Studies. Journal of Critical Realism, 5(1), 1–31. https://doi.org/10.1558/jocr.v5i1.1
Patterson, J., Wyborn, C., Westman, L., Brisbois, M. C., Milkoreit, M., & Jayaram, D. (2021). The political effects of emergency frames in sustainability. Nature Sustainability, 4(10), 841-850.
Pawson, R., & Tilley, N. (1997). *Realistic evaluation*. sage.
Pearce, B. J., & Ejderyan, O. (2020). Joint problem framing as reflexive practice: Honing a transdisciplinary skill. Sustainability Science, 15(3), 683–698. https://doi.org/10.1007/s11625-019-00744-2
Pel, B., Raven, R., & van Est, R. (2020). Transitions governance with a sense of direction: synchronization challenges in the case of the dutch 'Driverless Car'transition. *Technological Forecasting and Social Change*, *160*, 120244.
Penders, B., & Shaw, D. M. (2020). Civil disobedience in scientific authorship: Resistance and insubordination in science. Accountability in Research, 27(6), 347–371. https://doi.org/10.1080/08989621.2020.1756787
Pereira, L., Karpouzoglou, T., Doshi, S., & Frantzeskaki, N. (2015). Organising a safe space for navigating social-ecological transformations to sustainability. *International journal of environmental research and public health*, *12*(6), 6027-6044.
Pereira, L., Frantzeskaki, N., Hebinck, A., Charli-Joseph, L., Drimie, S., Dyer, M., ... & Vervoort, J. M. (2020). Transformative spaces in the making: key lessons from nine cases in the Global South. *Sustainability Science*, *15*(1), 161-178.

Pereira, L. M., Karpouzoglou, T., Frantzeskaki, N., & Olsson, P. (2018). Designing transformative spaces for sustainability in social-ecological systems. Ecology and Society, 23(4).
Pesch, U., Spekkink, W., & Quist, J. (2018). Local sustainability initiatives: Innovation and civic engagement in societal experiments. European Planning Studies, 1–18. https://doi.org/10.1080/09654313.2018.1464549
Pullman, P. (2002) "From Exeter to Jordan," Oxford Today: The University Magazine 14, no. 3 (Trinity), 3.
Piotrowski, M. (2017). Writing in Cramped Spaces. Reconceptualizing Educational Research Methodology, 8(3). https://doi.org/10.7577/rerm.2552
Pohl, C., Pearce, B., Mader, M., Senn, L., and Krütli, P. (2020). Integrating systems and design thinking in transdisciplinary case studies. GAIA Ecol. Perspect. Sci. Soc. 29, 258–266. doi: 10.14512/gaia.29.4.11
Poli, R. (2011). Steps toward an explicit ontology of the future. *Journal of Futures Studies*, *16*(1), 67-78.
Polk, M. (2014). Achieving the promise of transdisciplinarity: A critical exploration of the relationship between transdisciplinary research and societal problem solving. Sustainability Science, 9(4), 439–451. https://doi.org/10.1007/s11625-014-0247-7
Popper, K. (2005). The logic of scientific discovery. Routledge.
Pörtner, H. O., Roberts, D. C., Adams, H., Adler, C., Aldunce, P., Ali, E., ... & Birkmann, J. (2022). Climate change 2022: Impacts, adaptation and vulnerability. IPCC Sixth Assessment Report.
Priebe, J., Mårald, E., & Nordin, A. (2021). Narrow pasts and futures: How frames of sustainability transformation limit societal change. Journal of Environmental Studies and Sciences, 11(1), 76–84. https://doi.org/10.1007/s13412-020-00636-3
Puerari, E., de Koning, J., von Wirth, T., Karré, P., Mulder, I., & Loorbach, D. (2018). Co-Creation Dynamics in Urban Living Labs. Sustainability, 10(6), 1893. https://doi.org/10.3390/su10061893
Quist, J. (2007). *Backcasting for a sustainable future: the impact after 10 years*. Eburon Uitgeverij BV.
Raven, R., Schot, J., & Berkhout, F. (2012). Space and scale in socio-technical transitions. Environmental Innovation and Societal Transitions, 4, 63–78. https://doi.org/10.1016/j.eist.2012.08.001
Raven, R., Van den Bosch, S., & Weterings, R. (2010). Transitions and strategic niche management: Towards a competence kit for practitioners. International Journal of Technology Management, 51(1), 57–74.
Reed, M. S., Evely, A. C., Cundill, G., Fazey, I., Glass, J., Laing, A., ... & Stringer, L. C. (2010). What is social learning?. Ecology and society, 15(4).
Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. Biological Conservation, 141(10), 2417–2431. https://doi.org/10.1016/j.biocon.2008.07.014
Richardson, L., & St Pierre, E. (1994). Writing: a method of inquiry. *Denzin Norman i Yvonna Lincoln Handbook of Qualitative Research, Thousand Oaks, London, New Delhi: Sage*.
Rittel, H. W., & Webber, M. M. (1973). Planning problems are wicked. Polity, 4(155), 169.
Roberts, C., Geels, F. W., Lockwood, M., Newell, P., Schmitz, H., Turnheim, B., & Jordan, A. (2018). The politics of accelerating low-carbon transitions: Towards a new research agenda. Energy Research & Social Science, 44, 304–311. https://doi.org/10.1016/j.erss.2018.06.001

Robinson, J. B. (1988). Unlearning and backcasting: Rethinking some of the questions we ask about the future. Technological Forecasting and Social Change, 33(4), 325–338. https://doi.org/10.1016/0040-1625(88)90029-7
Robinson, J. B. (1990). Futures under glass. Futures, 22(8), 820–842. https://doi.org/10.1016/0016-3287(90)90018-D
Robinson, J. (2003). Future subjunctive: backcasting as social learning. Futures, 35(8), 839-856.
Robinson, J. (2004). Squaring the circle? Some thoughts on the idea of sustainable development. Ecological Economics, 48(4), 369–384. https://doi.org/10.1016/j.ecolecon.2003.10.017
Robinson, J. (2008). Being undisciplined: Transgressions and intersections in academia and beyond. Futures, 40(1), 70–86. https://doi.org/10.1016/j.futures.2007.06.007
Rockström, J., Steffen, W., Noone, K., Persson, \AAsa, Chapin III, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., & Schellnhuber, H. J. (2009). A safe operating space for humanity. Nature, 461(7263), 472.
Rosa, H. (2013). Social acceleration. In Social Acceleration. Columbia University Press.
Rosenberg, E., O'Donoghue, R., & Olvitt, L. (2008). Methods and processes to support change-oriented learning.
Rosenberg, E. (2020). Editorial for Special Issue: Education for Sustainability in a Time of Crises. Southern African Journal of Environmental Education, 36.
Rosenberg, N., & Nathan, R. (1982). *Inside the black box: technology and economics*. cambridge university press.
Ross, K., & Mitchell, C. (2018). Transforming transdisciplinarity: An expansion of strong transdisciplinarity and its centrality in enabling effective collaboration. In Transdisciplinary Theory, Practice and Education (pp. 39–56). Springer.
Rotmans, J., Kemp, R., & van Asselt, M. (2001). More evolution than revolution: Transition management in public policy. Foresight, 3(1), 15–31. https://doi.org/10.1108/14636680110803003
Saldaña, J. (2021). The coding manual for qualitative researchers. The coding manual for qualitative researchers, 1-440.
Sandberg, J., & Alvesson, M. (2011). Ways of constructing research questions: Gap-spotting or problematization? Organization, 18(1), 23–44. https://doi.org/10.1177/1350508410372151
Sanders, E. B. N., & Stappers, P. J. (2008). Co-creation and the new landscapes of design. *Co-design*, *4*(1), 5-18.
Sayer, A. (2000). Realism and social science. London: Sage
Sayer, A. (2011). Why things matter to people: Social science, values and ethical life. Cambridge University Press.
Sayer, R. A. (1992). Method in social science: A realist approach. Routledge. http://site.ebrary.com/id/10060928
Schäpke, N., Stelzer, F., Caniglia, G., Bergmann, M., Wanner, M., Singer-Brodowski, M., Loorbach, D., Olsson, P., Baedeker, C., & Lang, D. J. (2018). Jointly Experimenting for Transformation? Shaping Real-World Laboratories by Comparing Them. GAIA - Ecological Perspectives for Science and Society, 27(1), 85–96. https://doi.org/10.14512/gaia.27.S1.16
Schlindwein, S. L., & Ison, R. (2004). Human knowing and perceived complexity: implications for systems practice. Emergence: Complexity and Organization, 6(3), 27-32.

Scholz, R. (2017). The Normative Dimension in Transdisciplinarity, Transition Management, and Transformation Sciences: New Roles of Science and Universities in Sustainable Transitioning. Sustainability, 9(6), 991. https://doi.org/10.3390/su9060991

Schot, J. (1998). The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the nineteenth century. History and Technology, an International Journal, 14(3), 173–200.

Schot, J., & Geels, F. W. (2008). Strategic niche management and sustainable innovation journeys: Theory, findings, research agenda, and policy. Technology Analysis & Strategic Management, 20(5), 537–554. https://doi.org/10.1080/09537320802292651

Schön, D. A. (2008). The Reflective Practitioner: How Professionals Think In Action. New York, NY: Basic Books.

Scoones, I., Newell, P., & Leach, M. (2015). The politics of green transformations. In The Politics of Green Transformations (pp. 19–42). Routledge.

Scoones I, Stirling A, Abrol D, Atela J, Charli-Joseph L, Eakin H, Ely, A. et al. (2020) Transformations to sustainability: combining structural, systemic and enabling approaches. Curr Opin Environm Sustain 42:65–75. https://doi.org/10.1016/j.cosust.2019.12.004

Sellberg, M. M., Cockburn, J., Holden, P. B., & Lam, D. P. (2021). Towards a caring transdisciplinary research practice: Navigating science, society and self. Ecosystems and People, 17(1), 292-305.

Senge, P., Hamilton, H., & Kania, J. (2015). The dawn of system leadership. *Stanford Social Innovation Review*, *13*(1), 27-33.

Sengers, F., Wieczorek, A. J., & Raven, R. (2016). Experimenting for sustainability transitions: A systematic literature review. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2016.08.031

Seyfang, G., Haxeltine, A., Hargreaves, T., & Longhurst, N. (2010). Energy and communities in transition: Towards a new research agenda on agency and civil society in sustainability transitions. CSERGE working paper EDM.

Sfard, A. (1998). On two metaphors for learning and the dangers of choosing just one. Educational Researcher, 27(2), 4–13.

Sheller, M. (2022). The End of Flying: Coronavirus Confinement, Academic (Im) mobilities and Me. In *Academic Flying and the Means of Communication* (pp. 53-77). Palgrave Macmillan, Singapore.

Sheehy, M. (2004). Between a thick and a thin place: Changing literacy practices. In K. M. Leander & M. Sheey (Eds.), Spatializing literacy research and practice (pp. 91–114). New York: Peter Lang.

Shove, E., & Walker, G. (2007). Caution! Transitions Ahead: Politics, Practice, and Sustainable Transition Management. Environment and Planning A, 39(4), 763–770. https://doi.org/10.1068/a39310

Singer-Brodowski, M., Beecroft, R., & Parodi, O. (2018). Learning in Real-World Laboratories: A Systematic Impulse for Discussion. GAIA - Ecological Perspectives for Science and Society, 27(1), 23–27. https://doi.org/10.14512/gaia.27.S1.7

Smith, A., & Raven, R. (2012). What is protective space? Reconsidering niches in transitions to sustainability. Research Policy, 41(6), 1025–1036. https://doi.org/10.1016/j.respol.2011.12.012

Smith, A., Stirling, A., & Berkhout, F. (2005). The governance of sustainable socio-technical transitions. Research Policy, 34(10), 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005

Smith, T. S. J. (2017). Of Makerspaces and Hacklabs: Emergence, Experiment and Ontological Theatre at the Edinburgh Hacklab, Scotland. Scottish Geographical Journal, 133(2), 130–154. https://doi.org/10.1080/14702541.2017.1321137
Smith, N. (2006). There's no such thing as a natural disaster. *Understanding Katrina: perspectives from the social sciences*, *11*.
Sneddon, C., Howarth, R. B., & Norgaard, R. B. (2006). Sustainable development in a post-Brundtland world. Ecological Economics, 57(2), 253–268. https://doi.org/10.1016/j.ecolecon.2005.04.013
Soja, E. W. (1989). *Postmodern geographies: The reassertion of space in critical social theory*. Verso.
Solow, R. (1993). An almost practical step toward sustainability. 11.
Sovacool, B. K., & Hess, D. J. (2017). Ordering theories: Typologies and conceptual frameworks for sociotechnical change. Social Studies of Science, 47(5), 703–750.
Sovacool, B. K., Axsen, J., & Sorrell, S. (2018). Promoting novelty, rigor, and style in energy social science: Towards codes of practice for appropriate methods and research design. Energy Research & Social Science, 45, 12–42. https://doi.org/10.1016/j.erss.2018.07.007
Star, S. L., & Griesemer, J. R. (1989). Institutional ecology,translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social studies of science*, *19*(3), 387-420.
Stake, R. E. (1995). The art of case study research. sage.
Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*, *2*(1), 81-98.Sterling, S., & Orr, D. (2001). Sustainable education: Re-visioning learning and change (Vol. 6). Totnes: Green Books for the Schumacher Society.
Stirling, A. (2009). Direction, distribution and diversity! Pluralising progress in innovation, sustainability and development.
Stirling, A. (2008). "Opening Up" and "Closing Down": Power, Participation, and Pluralism in the Social Appraisal of Technology. *Science, Technology, & Human Values*, *33*(2), 262–294. https://doi.org/10.1177/0162243907311265
Stirling, A. (2016). Knowing Doing Governing: Realizing Heterodyne Democracies. In J.-P. Voß & R. Freeman (Eds.), Knowing Governance (pp. 259–289). Palgrave Macmillan UK. https://doi.org/10.1057/9781137514509_12
Stirling, A. (2010). Keep it complex. Nature, 468(7327), 1029–1031. https://doi.org/10.1038/4681029a
Strasser, B. J., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2018). "Citizen Science"? Rethinking Science and Public Participation. Science & Technology Studies, 52–76. https://doi.org/10.23987/sts.60425
Stripple, J., Nikoleris, A., & Hildingsson, R. (2021). Carbon ruins: Engaging with post-fossil transitions through participatory world-building. Politics and Governance, 9(2), 87.
Suter, W. (2012). Introduction to Educational Research: A Critical Thinking Approach. SAGE Publications, Inc. https://doi.org/10.4135/9781483384443
Sword, H. (2012). Stylish academic writing. Harvard University Press.
Temper, L., McGarry, D., & Weber, L. (2019). From academic to political rigour: Insights from the 'Tarot'of transgressive research. Ecological Economics, 164, 106379.
Temple, P. (2008). Learning spaces in higher education: An under-researched topic. London Review of Education, 6(3), 229–241. https://doi.org/10.1080/14748460802489363

Thomas, H. (2010). Learning spaces, learning environments and the dis'placement' of learning. British Journal of Educational Technology, 41(3), 502–511. https://doi.org/10.1111/j.1467-8535.2009.00974.x
Thomas, J., & Harden, A. (2008). Methods for the thematic synthesis of qualitative research in systematic reviews. BMC Medical Research Methodology, 8(1). https://doi.org/10.1186/1471-2288-8-45
Thompson Klein, J. (2010). Creating interdisciplinary campus cultures: A model for strength and sustainability. AAC&U and Jossey-Bass.
Tilbury, D. (2016). "Student engagement and leadership in higher education for sustainability," in Routledge Handbook of Higher Education for Sustainable Development, eds M. Barth, G. Michelsen, M. Rieckmann, and I. Thomas (Oxford: Routledge), 273–286.
Torrens, J., Schot, J., Raven, R., & Johnstone, P. (2019). Seedbeds, harbours, and battlegrounds: On the origins of favourable environments for urban experimentation with sustainability. *Environmental Innovation and Societal Transitions*, *31*, 211–232. https://doi.org/10.1016/j.eist.2018.11.003
Törnberg, A. (2021). Prefigurative politics and social change: a typology drawing on transition studies. Distinktion: Journal of Social Theory, 22(1), 83-107
Tracy, S. J. (2010). Qualitative Quality: Eight "Big-Tent" Criteria for Excellent Qualitative Research. Qualitative Inquiry, 16(10), 837–851. https://doi.org/10.1177/1077800410383121
Turner Victor W. 1967. The forest of symbols. Ithica, N..Y. Cornell University Press
Turner, C., & Sandahl, M. (2016). Learning objectives for a degree of Doctor – activities and assessment. 5.
Ullström, S., Stripple, J., & Nicholas, K. A. (2021). From aspirational luxury to hypermobility to staying on the ground: changing discourses of holiday air travel in Sweden. Journal of Sustainable Tourism, 1-18
Ulmer, J. B. (2017). Writing slow ontology. Qualitative Inquiry, 23(3), 201-211.
Ulrich, W. (2003). Beyond methodology choice: critical systems thinking as critically systemic discourse. Journal of the Operational Research Society, 54(4), 325-342.
UNESCO. (2014). Shaping the Future We Want: UN Decade of Education for Sustainable Development (2005-2014) : Final Report.
United Nations. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. United Nations.
Unruh, G. C. (2000). Understanding carbon lock-in. Energy Policy, 28(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7
van den Bosch, S., & Rotmans, J. (2008). Deepening, Broadening and Scaling up: A Framework for Steering Transition Experiments.
van der Hel, S. (2016). New science for global sustainability? The institutionalisation of knowledge co-production in Future Earth. Environmental science & policy, 61, 165-175
van Beek, L., Hajer, M., Pelzer, P., van Vuuren, D., & Cassen, C. (2020). Anticipating futures through models: the rise of Integrated Assessment Modelling in the climate science-policy interface since 1970. *Global Environmental Change*, *65*, 102191.
van Kerkhoff, L., & Lebel, L. (2006). Linking Knowledge and Action for Sustainable Development. Annual Review of Environment and Resources, 31(1), 445–477. https://doi.org/10.1146/annurev.energy.31.102405.170850

van Mierlo, B., & Beers, P. J. (2018). Understanding and governing learning in sustainability transitions: A review. Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2018.08.002
van Oers, L., Feola, G., Moors, E., & Runhaar, H. (2021). The politics of deliberate destabilisation for sustainability transitions. *Environmental Innovation and Societal Transitions*, *40*, 159-171.
Van Poeck, K., Östman, L., & Block, T. (2018). Opening up the black box of learning-by-doing in sustainability transitions. Environmental Innovation and Societal Transitions. https://doi.org/10.1016/j.eist.2018.12.006
Elder-Vass, D. (2022). Pragmatism, critical realism and the study of value. *Journal of Critical Realism*, 1-27.
Vergragt, P. J., & Quist, J. (2011). Backcasting for sustainability: Introduction to the special issue. *Technological forecasting and social change*, *78*(5), 747-755.
Verlie, B. (2019). Bearing worlds: learning to live-with climate change. Environmental Education Research, 25:5, 751-766.
Vervoort, J. M., Kok, K., van Lammeren, R., & Veldkamp, T. (2010). Stepping into futures: exploring the potential of interactive media for participatory scenarios on social-ecological systems. Futures, 42(6), 604-616.
Vetter, J. (2011). Introduction: Lay Participation in the History of Scientific Observation. Science in Context, 24(2), 127–141. https://doi.org/10.1017/S0269889711000032
Vilsmaier, U., & Lang, D. J. (2015). Making a difference by marking the difference: constituting in-between spaces for sustainability learning. *Current Opinion in Environmental Sustainability*, *16*, 51-55.
Vogel, C., & O'Brien, K. (2022). Getting to the heart of transformation. Sustainability Science, 17(2), 653-659.
Von Foerster, H. (1979). Cybernetics. *Communication and Control in Society*, 5.
Von Wirth, T., Fuenfschilling, L., Frantzeskaki, N., & Coenen, L. (2019). Impacts of urban living labs on sustainability transitions: Mechanisms and strategies for systemic change through experimentation. *European Planning Studies*, *27*(2), 229-257.
Voss, J.-P., & Kemp, R. (2005). Reflexive Governance: Learning to cope with fundamental limitations in steering sustainable development. Futures, 00–01.
Voytenko, Y., McCormick, K., Evans, J., & Schliwa, G. (2016). Urban living labs for sustainability and low carbon cities in Europe: Towards a research agenda. Journal of Cleaner Production, 123, 45–54. https://doi.org/10.1016/j.jclepro.2015.08.053
Waas, T., Hugé, J., Verbruggen, A., & Wright, T. (2011). Sustainable Development: A Bird's Eye View. Sustainability, 3(10), 1637–1661. https://doi.org/10.3390/su3101637
Walker, G., & Shove, E. (2007). Ambivalence, Sustainability and the Governance of Socio-Technical Transitions. Journal of Environmental Policy & Planning, 9(3–4), 213–225. https://doi.org/10.1080/15239080701622840
Wallin, P., & Adawi, T. (2018). The reflective diary as a method for the formative assessment of self-regulated learning. *European Journal of Engineering Education*, *43*(4), 507-521.
Wals, A. E. (2015). Beyond unreasonable doubt. Education and learning for socio-ecological sustainability in the Anthropocene. Wageningen University.
Wals, A. E., & Jickling, B. (2002). "Sustainability" in higher education: From doublethink and newspeak to critical thinking and meaningful learning. International Journal of Sustainability in Higher Education.
Wamsler, C., & Brink, E. (2018). Mindsets for sustainability: Exploring the link between mindfulness and sustainable climate adaptation. *Ecological Economics*, *151*, 55-61.

Wanner, M., Hilger, A., Westerkowski, J., Rose, M., Stelzer, F., & Schäpke, N. (2018). Towards a Cyclical Concept of Real-World Laboratories: A Transdisciplinary Research Practice for Sustainability Transitions. DisP - The Planning Review, 54(2), 94–114. https://doi.org/10.1080/02513625.2018.1487651

WCED, S. W. S. (1987). World commission on environment and development. Our Common Future, 17(1), 1–91.

Weed, M. (2005). ' Meta interpretation': A method for the interpretive synthesis of qualitative research. Forum Qualitative Sozialforschung/Forum: Qualitative Social Research, 6(1).

Weiland, S., Bleicher, A., Polzin, C., Rauschmayer, F., & Rode, J. (2017). The nature of experiments for sustainability transformations: A search for common ground. Journal of Cleaner Production, 169, 30–38. https://doi.org/10.1016/j.jclepro.2017.06.182

Wenger, E. (2010). Communities of practice and social learning systems: The career of a concept. In Social learning systems and communities of practice (pp. 179–198). Springer.

West, S., van Kerkhoff, L., & Wagenaar, H. (2019). Beyond "linking knowledge and action": Towards a practice-based approach to transdisciplinary sustainability interventions. Policy Studies, 1–22. https://doi.org/10.1080/01442872.2019.1618810

Westley, F., Olsson, P., Folke, C., Homer-Dixon, T., Vredenburg, H., Loorbach, D., ... & Van Der Leeuw, S. (2011). Tipping toward sustainability: emerging pathways of transformation. *Ambio*, *40*(7), 762-780.

Wiener, N. (1948). Time, communication, and the nervous system. Annals of the New York Academy of Sciences, 50(4), 197-220.

Williams, S. (2019) The splash and the ripples: assessing sustainability transition experiments. University of British Columbia

Williams, S., & Doyon, A. (2020). The Energy Futures Lab: A case study of justice in energy transitions. *Environmental innovation and societal transitions*, *37*, 290-301.

Williams, S., & Robinson, J. (2020). Measuring sustainability: An evaluation framework for sustainability transition experiments. Environmental Science & Policy, 103, 58–66. https://doi.org/10.1016/j.envsci.2019.10.012

Wittmayer, J. M., & Schäpke, N. (2014). Action, research and participation: roles of researchers in sustainability transitions. Sustainability science, 9(4), 483-496.

Wittmayer, J. M., Avelino, F., van Steenbergen, F., & Loorbach, D. (2017). Actor roles in transition: Insights from sociological perspectives. Environmental Innovation and Societal Transitions, 24, 45–56. https://doi.org/10.1016/j.eist.2016.10.003

Woiwode, C., Schäpke, N., Bina, O., Veciana, S., Kunze, I., Parodi, O., ... & Wamsler, C. (2021). Inner transformation to sustainability as a deep leverage point: fostering new avenues for change through dialogue and reflection. Sustainability Science, 16(3), 841-858.

Woolley, J. P., McGowan, M. L., Teare, H. J. A., Coathup, V., Fishman, J. R., Settersten, R. A., Sterckx, S., Kaye, J., & Juengst, E. T. (2016). Citizen science or scientific citizenship? Disentangling the uses of public engagement rhetoric in national research initiatives. BMC Medical Ethics, 17(1). https://doi.org/10.1186/s12910-016-0117-1

Wright, E. O. (2010). Envisioning real utopias (Vol. 98). Verso London.

Wynes, S., & Donner, S. D. (2018). Addressing greenhouse gas emissions from business-related air travel at public institutions: a case study of the University of British Columbia. Victoria, BC: Pacific Institute for Climate Solutions.

Yang, K., Schot, J., & Truffer, B. (2022). Shaping the directionality of sustainability transitions: the diverging development patterns of solar photovoltaics in two Chinese provinces. *Regional Studies*, *56*(5), 751-769.

Yin, R. K. (2011). Qualitative research from start to finish. Guilford Press.
Ziervogel G, Cowen A, Ziniades J (2016) Moving from adaptive to transformative capacity: building foundations for inclusive, thriving, and regenerative Urban settlements. Sustainability 8(10):955. https://doi.org/10.3390/su8090955
Zizek, S. (1989) The Sublime Object of Ideology. London: Verso.