THESIS FOR THE DEGREE OF LICENTIATE OF PHILOSOPHY

In search of seeds

Exploring and classifying sustainability-oriented labs in real-world contexts

GAVIN MCCRORY

Division Physical Resource Theory

Department of Space, Earth and Environment

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2021

In search of seeds

Exploring and classifying sustainability-oriented labs in real-world contexts

GAVIN MCCRORY

Department of Space, Earth and Environment
Chalmers University of Technology
SE-412 96 Gothenburg
Sweden
Telephone + 46 (0)31-772 1000

Printed by Chalmers Reproservice
Gothenburg, Sweden 2021

In search of seeds

Exploring and classifying sustainability-oriented labs in real-world contexts

GAVIN MCCRORY

Division Physical Resource Theory
Department of Space, Earth and Environment
Chalmers University of Technology

Abstract

In 2015, the necessity of fundamental change was outlined in the universal, transnational agreement, Agenda 2030, under the headline of "transforming our world". Underlying transformation, integration, and universality, Agenda 2030 calls for guided ethical and moral action in addition to earnest scientific and technological change. Sustainability transitions provide an organizing frame to conceptualize change at the level of systems. It does this within an explicitly normative field of research and practice, committed to understanding and navigating transitions towards sustainability.

Alongside socio-technical niches and experiments, labs in real world contexts have emerged as appealing entities that situate and localize around complex sustainability challenges. Their diverse form and positive connotations suggest a novel form of experimentation with purposeful and transformative aspirations. Yet, labs in real-world contexts hold different normative commitments, many of which are arguably tangential to sustainability. The purpose of this thesis is to establish a normative understanding of laboratories in real-world contexts through the adoption of sustainability as an organizing concept. Methodologically, my research emerged from and was shaped by one interconnected process, a systematic yet exploratory review.

In this thesis, I generate knowledge claims on a collection of labs that intersect disciplines and areas of application. I derive seven research communities linked to sustainability-oriented labs in real-world contexts, and present labs as a combination of spaces, processes and ways of organizing. I develop an empirically grounded typology of labs according to engagement with sustainability as a generic matter of concern, substantiated in place. This typology illuminates similarities and differences across six different lab types. I then point towards reflexive governance as a helpful extension for further understanding labs in the context of transitions towards sustainability. Moving forward, I plan to adopt learning as a lens for qualitative case-based inquiry, enabling a contextual understanding of lab processes in practice.

Keywords: Sustainability transitions, laboratories, systematic review, reflexive governance, transdisciplinarity, learning

List of appended 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 particular sections of the paper.

II **McCrory, G.,** Holmén, J., Schäpke, N., & Holmberg, J (2021). Taking sustainability seriously: an empirical typology of sustainability-oriented labs. *Manuscript submitted to* journal Environmental Innovation and Societal Transitions (EIST)

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, for the curation of data, manuscript writing and coordinating contributions across all co-authors. JH[1], NS & JH[2] provided comments and feedback in the drafting and finalization of the manuscript.

Related publications 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.

Acknowledgements

Although more of an "in-progress" than anything, this is, as far as I am aware, the first licentiate thesis within my family. Its development has been informed by many different thinkers and writers, as is reflected in the mixed bag of a reference list. There are many more around me that have left an imprint on my research, as well my development as a doctoral candidate, some of whom I would like to acknowledge.

John, thank you for caring about people in processes of change. You bring a positivity that I admire in our encounters, and that I find to be rare in research. Without your true care for students, education and learning as central to sustainability transformations, this doctoral experience and thesis would not have been the same. To Tom, I am grateful for the time and resources that you invest in engaging with my interests authentically, and from where I am. You bring a balance to many of the conversations that we have had. I'm excited to see what we can develop over the remaining two years of my doctoral journey.

To Niko, thanks for sharing the first 2 years of our journey in Chalmers and Gothenburg together. To Johan, thanks for being a close colleague and friend. You were the first person that I met at Chalmers on the sixth of January 2018. Since then, we've exchanged ideas, taught, researched and learned together. We've shared two offices in different divisions, supported each other's work and turned to each other in both challenging and exciting times. We've also drank beer in Gothenburg, Lüneburg, Brighton and Manchester. To Jinxi, thanks for being a fantastic officemate.

Thanks to all of my colleagues and friends from FRT for the wonderful time spent together in Gbg. Thank you to Mascha, Mudit, Erik, Valentina and the many others from ESA for welcoming me into your home. A special thanks to my nearest and dearest from different places around the world – the MARMLS from North Belfast, the LUMES group from all over the place, the Coxes, Charlie and Lele from Avenue de la Brabançonne.

To all of the students and staff involved in Challenge Lab. Thanks for bringing so much knowledge, ambition and enthusiasm into the spaces that we try to develop. Thanks to Annica, Viktor, Niklas and Jakob, for trusting me to support your ideas during your thesis.

To my family. I still don't think you know what I "do", and I'll never blame or judge you for that. Despite the differences in our lives, you have remained endlessly curious, supportive and caring. Your chaotic digital calls bring me comfort that even as I live elsewhere, things at home kind of remain the same.

Specifically, to mum and dad. You made this possible in ways that I might never be able to understand, and I will always admire you both for that.

Finally, Elin – thank you for a steady supply of rice crackers, snacks and much-needed respite at important times. I'm sorry for talking about philosophy of science with you. I know you don't care. I can't guarantee that it won't continue, but I'll try my best. And sorry for the hours of screen light and keyboard noises that disrupted your sleep in our little box.

Table of Contents

1 Introduction

> Another circumstance strengthened and confirmed these feelings. Soon after my arrival in the hovel, I discovered some papers in the pocket of the dress which I had taken from your laboratory. At first, I had neglected them; but now that I was able to decypher the characters in which they were written, I began to study them with diligence. It was your journal of the four months that preceded my creation. You minutely described in these papers every step you took in the progress of your work; this history was mingled with accounts of domestic occurrences. You doubtless recollect these papers. Here they are. Everything is related in them which bears reference to my accursed origin; the whole detail of that series of disgusting circumstances which produced it is set in view.
>
> (Shelley, 1818, ch. 15)

1.1 Research framing

In 2015, the necessity of fundamental societal change was outlined in the universal, transnational agreement, Agenda 2030, under the headline of "transforming our world". The agreed upon UN 2030 Agenda for Sustainable Development includes 17 Sustainable Development Goals (SDGs) (United Nations, 2015), ranging from ending poverty and establishing gender equality to promoting sustainable cities and halting climate change. When viewed in their entirety, Agenda 2030 claims to have a comprehensive goal-based approach to grapple with persistent challenges faced by modern society. It carries aspirations to guide multiple and major societal change processes in the coming decades. The ambitions of agenda 2030, in achieving transformation and integration, necessitate guided ethical and moral action in addition to earnest scientific and technological change. The current challenges to development are, amongst other things, challenges of contemporary governance. They mark a continuous tension between controlling under conditions of immense uncertainty and urgency, and guiding burgeoning opportunities to collectively create, to resist, and to hope for a better future.

Sustainability transitions provide an organizing frame for conceptualizing change at the level of systems. Transitions can be understood as macro-scale co-evolutionary developments that occur within systems characterized by complexity. The systems central to transitions are often referred to as coupled socio-ecological (Jerneck et al., 2011) or socio-technical (Geels, 2002; Sovacool & Hess, 2017), depending on the emphasis placed on their focus and respective boundaries. Socio-technical change directs focus towards the non-linear developments of society and technology, and draws predominantly from neo-institutional theory, evolutionary economics, science

and technology and innovation studies (Geels, 2010). In recent years, attention has broadened beyond analytically descriptive accounts of historic socio-technical change (Feola, 2015; Köhler et al., 2019; Loorbach et al., 2017). Now, transitions insights are produced by 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). One uniting ambition, whether from the past, present or towards the future, is a focus on transitions as normative endeavours with an interest in desirable change (Köhler et al., 2019; Loorbach et al., 2017; Smith et al., 2005). This shared emphasis is evident in the commitment towards "transitions towards sustainability" (Smith et al., 2005a), including the recent normative agenda of "accelerating" transitions towards sustainability (Roberts et al., 2018).

In recent years, both the adoption of the term lab and its appeal as catalysts of change have grown in science, policy and practice. They 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 transnational and translocal (Loorbach et al., 2020). At the level of practice, the European Network of Living Labs consists of 150+ lab initiatives globally, and the UNDP developed a learning network of 90 accelerator labs. Policy labs co-develop regulatory conditions for policy experimentation[1]. Alongside socio-technical niches (Coenen et al., 2010; Schot & Geels, 2008; Smith & Raven, 2012) and experiments (Bosch-Ohlenschlager, 2010; Caniglia et al., 2017; Pesch et al., 2018; Weiland et al., 2017), labs in real world contexts have emerged as appealing, novel and highly complex entities that situate and localize engagement with complex sustainability related challenges (Evans & Karvonen, 2014; Nevens, Frantzeskaki, Gorissen, & Loorbach, 2013; Schäpke et al., 2018). Broadly speaking, these labs constitute bounded settings for experimentation and testing of innovative solutions to sustainability challenges in collaboration with various actors (Bulkeley & Betsill, 2013; Evans et al., 2016). 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).

1.2 Central research curiosity

The starting point for my research gravitates around a research curiosity[2]. The diversity alluded to above – the practical and academic attention towards labs in real-world

[1]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/

contexts, as well as the generally positive connotations related to labs – could well indicate the presence of a novel form of experimentation, driven by deliberate, purposeful and transformative aspirations of place-based change. Yet, with positive associations comes the need to consider these initiatives in the context of transitions and transformations towards sustainability. It is worth recalling that 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). Labs in real-world contexts express different normative commitments in research and practice. Furthermore, many of these commitments may be arguably tangential to sustainability, either by equating sustainability to the environmental performance or the financial longevity of lab activities (Hossain et al., 2019). This should not be surprising but expected of a phenomenon whose roots are dispersed across both scientific, practical and commercial domains. Perhaps more significantly, however; simplified understandings of sustainability have performative consequences for how labs are designed, evaluated (Williams & Robinson, 2020), and positioned in relation to transitions towards sustainability. It therefore triggered a curiosity in the extent to which sustainability could bridge disciplines and fields of practice by bringing together labs that are concerned with a normative ambition of a similar nature.

1.3 Guiding research questions

In approaching this curiosity, I rely upon two complementary research questions:

1. **How can sustainability-oriented labs in real-world contexts be understood?**
    - **a.** How are sustainability-oriented labs distinguishable at the sample level?
    - **b.** Which research communities are connected to sustainability-oriented labs?
    - **c.** How can lab practices be characterised in relation to sustainability?
2. **In which ways do sustainability-oriented labs engage with sustainability?**
    - **a.** Which similarities and differences can be observed amongst sustainability-oriented lab in how they engage with sustainability?

[2] Gap-spotting reflects an incremental approach to research contributions, where the ambition is to fill a deficit, reduce confusion or complement what is currently known about a topic (Sandberg & Alvesson, 2011). Research curiosities, puzzles or mysteries on the other hand, leave room for the creative role of research in interrogating existing understandings, introducing new or presenting alternative interpretations (Alvesson, 2013). Curiosities demand a balance between personal interests and societal significance when establishing a persuasive warrant for research (Alvesson & Sandberg, 2013; Gustafsson & Hagström, 2018).

So, where did this curiosity come from? Well, ideas for research emerge in various places and times across a research career. Through practical exposure, academic, professional and personal experiences, I have been aware of the overtly positive associations triggered by the "lab" in the real world. I have also experienced the diverse stances that exist in lab practices yet seem to be glossed over in different fields of research and practice. I observe that despite a rich landscape of initiatives, conversations tend to move in favour of unifying around dominant conceptualizations. Moreover, when connected to the need for explicitly normative change of a systemic nature, advocated from within the sustainability transitions community, it is striking that sustainability is broadly neglected from an understanding what labs are oriented towards. This remains disconcerting, given that levels of action, from the arena 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 many different ways that a lab can relate to change. In addition, the taken-for-granted character of the lab may depoliticize what is invariably a political and ethical form of action.

1.4 Research purpose and scope

The purpose of this thesis is to establish a normative understanding of laboratories in real-world contexts through the use of sustainability as an organizing concept. I combine both exploratory and classificatory approaches to support in the understanding of labs in real-world contexts. Together, the research questions emerged from and were shaped by one continuous research process, a systematic yet exploratory review. In pursuit of my research purpose, I have remained inclusive with regards to the sectors, thematic areas, geographical and institutional scopes that labs under study connect to. Rather than relying on existing labels and disciplinary boundaries, including the conceptual and theoretical baggage that they bring, I see this thesis as an attempt to re-focus. Like the lens on a camera, I try to bring into view those labs that harbour within their design a relation to sustainability. I then investigate these 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). This thesis is therefore aimed towards a relatively broad base of stakeholders. Whether academics, practitioners or pracademics my hope is that it appeals to those who share an interest in further informing and designing transitional processes towards sustainability.

As a phenomenon connected to a range of different disciplines, areas of practice and contexts, some decisions were needed to maintain a research scope. Firstly, this thesis is concerned with labs that explicitly take place in real-world contexts. Throughout the process of locating labs, I gradually excluded metaphorical or abstract references, nation states, regions and universities as labs, and companies. Although connected to

broader debates about laboratization (Guggenheim, 2012), the focus of this thesis is on understanding lab practices that are in contrast both to "placeless" and "consequent-free" laboratories that emerged in the late 19th century, as well as undefined use of lab as a metaphor for change. Secondly, I maintained a relatively open scope for interpretation regarding what sustainability means for particular labs. This was an aim of this research – to engage with sustainability as bridging concept, whose meaning is substantiated in place. This enables the classification and comparison of various labs depending on what sustainability means, as well as how it is engaged with as a concept.

1.5 Epistemological and ontological orientations

My research approach is broadly informed by a critical realist philosophy of science. Critical realism (CR) advocates ontological realism in the face of epistemological relativism. It holds that frameworks, theories and concepts should be viewed as provisional, reflecting the relative nature of knowledge in search of truth (Bhaskar et al., 1998). In addition, there is an ontological acceptance of the independent nature of reality, combined with a flexible epistemological approach to the partiality of knowledge produced about said reality.

Rather than a singular, dogmatic stance on CR, I relate to the more inclusive nature of critical realism in terms of epistemology. 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). Additionally, I see critical realism as a relevant alternative to positivism, where ontological reality is not limited to the merely observable. The tendency to do so – to reduce empirical observations of reality to reality itself (Popper, 2005) – is known as the epistemic fallacy, commonplace in criticisms of positivism from a CR perspective.

As ontological realists with an interest in the layered nature of reality and our knowledge of it, CR endeavours to look "behind" or "below" the empirical – as reflected by ontological domains of the empirical, the actual and the real (Bhaskar, 2013). 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)

In the context of my own PhD and this licentiate, a CR stance has been relatively implicit to date. I adopt an anti-reductionist stance when framing the relation between social and technical systems that are coupled and co-evolutionary (Mingers, 2014). In addition, I adhere to the provisional nature of knowledge generated in my research in making sense of labs in real-world contexts. I adopt a methodologically flexible stance when moving between methods and my data. This has subtly influenced the choice of methodological approach adopted in my licentiate, a form of systematic review process that emerged as an anti-positivist response to the synthesis of evidence. During my research beyond this licentiate, I expect that my relation to critical realism as an underpinning philosophy of science will grow also.

1.6 Thesis structure

This thesis is structured as follows. In the section that follows this introduction (section 2), I introduce the grounding elements and topical considerations relevant for this thesis, namely: Socio-technical transitions, sustainability and normativity and laboratories in real-world contexts. In section 3, I turn my attention towards the methodological approach underpinning this research. I do this by presenting an overall research methodology, before zooming in on the research strategies specific to Papers I and II. In section 4 I present and synthesize both papers as standalone pieces. In section 5, I contextualize both papers and this thesis through the form of a broad discussion on implications, methodological reflections and caveats. I then motivate areas of interest that follow this thesis, both in relation to Papers I and II, and in connection to the emergent opportunities that shape my personal doctoral journey, before concluding this in section 6.

2 Background

In this section, I introduce the central elements for this licentiate, namely: Socio-technical transitions, sustainability and normativity, and labs in real-world contexts (Fig. 1). It presents the authors and ideas that have shaped my thinking and work to date.

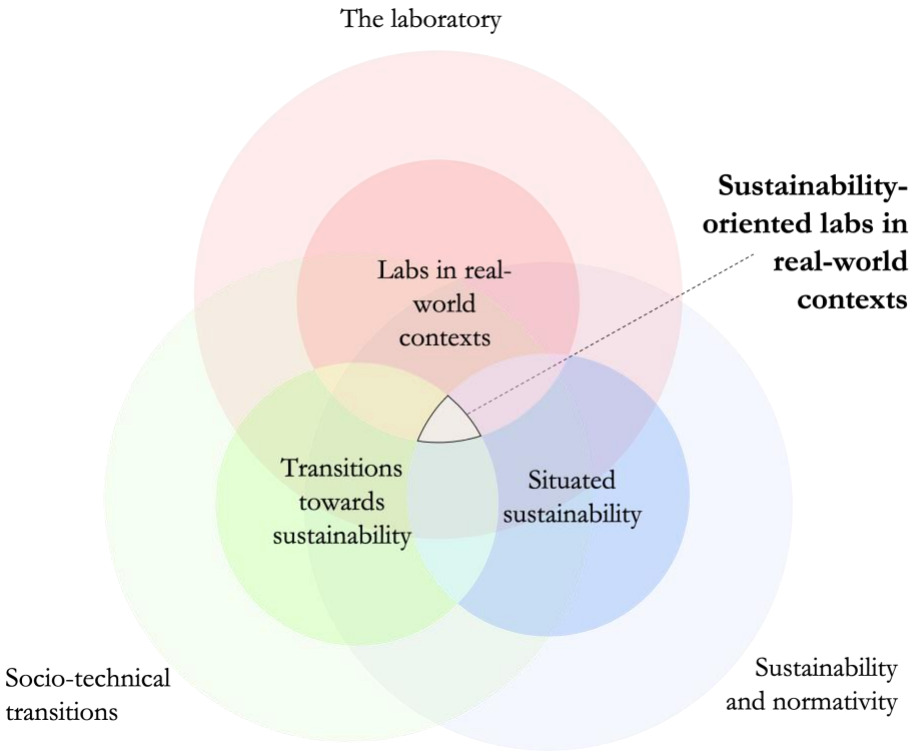


Figure 1: This thesis is situated within two overlapping fields of inquiry (transitions towards sustainability and situated sustainability) and concerns one object of study (laboratories in real-world contexts)

2.1 Socio-technical transitions

> Loosely defined, a transition denotes a long-term change in an encompassing system that serves a basic societal function (e.g., food production and consumption, mobility, energy supply and use, communication, etc.). In a transition, both the technical as well as the social/cultural dimensions of such a system change drastically. This emphasis on the co-evolution of technical and societal change distinguishes transitions from incremental processes, which are primarily characterised by technical change (through successive generations of technologies) with relatively little alteration of the societal embedding of these technologies.
>
> (Elzen et al., 2004, p. 652)

2.1.1 Transition logics

This licentiate is situated within the broader field of socio-technical transitions. Socio-technical transitions argue that, rather than single innovation trajectories shaped by market characteristics, socio-technical change arises as a complex interplay within a socio-technical system (Loorbach et al., 2017). In contrast to framing technology as the central element and "driver of change", this research field adopts a systems perspective that recognizes the embeddedness of different structures in society. Socio-technical systems are often conceptualized as a cluster of aligned elements such as technology, infrastructure, industry structures, markets, policy, legislation, knowledge, culture & norms. These interacting elements were traditionally conceived of in studying the provision of societal functions such as energy, mobility and food services (Geels, 2002). Whilst the co-evolutionary nature of such elements are dynamic over time, socio-technical systems are characterised by high degrees of complexity, uncertainty and ambivalence (Andersson, 2014; Smith et al., 2005; Walker & Shove, 2007). Systems of this kind exhibit a stability that is preserved by path-dependencies, lock-in effects and inertia (Geels, 2014; Unruh, 2000). Given the obduracy of socio-technical systems, transitions are relatively gradual over time, occurring across multiple generations.

Fundamental changes in socio-technical systems occur on a level of consumption and production, termed "system innovations" or "transitions" (Elzen et al., 2004; Geels, 2002; Grin et al., 2010). It is argued that transitions of this magnitude presuppose fundamental transformation, of a qualitative nature, that is both deep and broad. Deep in reference to the interactions between markets, societies and states in a liveable world across generations, as well as the nature and organization of such interactions (Wright, 2010). Broad in that both sides of many different and often overlapping "coins" are implicated in such change: production and consumption (Hargreaves et al., 2013; McLellan et al., 2016); urban and rural (Bulkeley & Betsill, 2013; Lawhon & Murphy, 2012); natural and social (Geels, 2005; Olsson & Jerneck, 2018); structural and agential (Fischer & Newig, 2016; McLellan et al., 2016; Seyfang, Haxeltine, Hargreaves, & Longhurst, 2010).

2.1.2 Transitions towards sustainability

In recent years, several developments in the field of sustainability transitions have occurred. Whilst previously concerned with providing a structured examination of the surrounding dynamics and mechanisms of socio-technical change (Geels, 2002; Schot, 1998), transitions research now includes a multitude of disciplines, frameworks and perspectives to engage with systems change. As a result, transitions are now studied through a broader set of dimensions, geographical locations and levels of analytical focus (Loorbach et al., 2017). Moreover, perspectives on transitions are not only

analytical-descriptive, but also explicitly change-oriented (Feola, 2015), with a growing set of approaches concerned with the governance of transitions towards sustainability (Grin et al., 2010; Loorbach, 2007; Rotmans et al., 2001). Finally, there is a recent urgency associated with transitions towards sustainability, driven by the need to induce systems change at a pace not previously seen before (Ehnert et al., 2018; Markard et al., 2020; Roberts et al., 2018).

Broadly speaking, transitions research and practice draws from multi-, inter-, and transdisciplinary forms of research (Loorbach et al., 2017). This has been partly shaped by a "reflexive" turn of sorts, where emphasis has shifted towards modes of experimentation, processes of learning and reflexive society-science interactions when entering uncertain terrain (Loorbach, 2007; Voss, Bauknecht & Kemp, 2006; Rotmans, Kemp, & van Asselt, 2001; Smith, Stirling, & Berkhout, 2005). These developments imply that it is possible to influence transitions and transformations, rather than respond to them. This also reflected in the research developments in both approaches, as well as the in broad movement from "government" to "governance", and more recently to "good governance" in sustainability narratives (Bulkeley & Betsill, 2013). Such prescriptive transitions practices draw from at least four different strands:

- Reflexive governance and experimentation Loorbach, 2007; Smith et al., 2005; Voss & Kemp, 2005)
- Transdisciplinarity and transformative science (Abson et al., 2017; Brandt et al., 2013; Lang et al., 2012; Polk, 2014)
- Action research and research-practice (Baxter & Eyles, 1997; Bradbury et al., 2019; Wittmayer et al., 2017)
- Systemic interventionism (Midgley, 2003; West et al., 2019)

Reflexive governance has been particularly influential in informing prescriptive transitions approaches that exist today. Carrying the view that transitions are not only historical processes to be studied, reflexive governance sees coordinated and directed systems change as necessary in averting the catastrophic changes expected e.g. in a warming planet (Meadowcroft, 2009; Stirling, 2016). 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). 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. Here "reflexivity is not so much a quality situated within any given body of governance knowledge, but about it" (Stirling, 2016). Instead, current modes of governing may be partly responsible for reinforcing multiple system conditions that are undesirable and unsustainable (Voss & Kemp, 2005). 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 ambivalence and uncertainty inherent in such transitions. As such:

> 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)

Of broad relevance for this thesis are situated forms of learning from practice (West et al., 2019), experimentation (Bosch-Ohlenschlager, 2010; Caniglia et al., 2017; Fazey et al., 2018; Pesch et al., 2018; Weiland et al., 2017) and systemic intervention (Bai et al., 2016; Bosch-Ohlenschlager, 2010; Fazey et al., 2018). This is for two reasons: 1) they exist as purposive efforts that call into question and challenge the boundaries between "knowing" and "doing" (Stirling, 2016) by openly engaging with processes of change characterized by uncertain outcomes (Loorbach et al., 2017; Rotmans, Kemp, & van Asselt, 2001; Smith, Stirling, & Berkhout, 2005; Voss & Kemp, 2005) and 2) within debates concerning transitions and transformation they are often suggested as settings where radical alternatives can be co-produced, shaped and performed in a limited space and time.

2.2 Sustainability and normativity

> 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)

2.2.1 Sustaining what, according to whom?

Across the last several decades in international environmental discourse, the term sustainability has garnered a multitude of meanings and definitions (see Hopwood et

al., 2005 for an overview). 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. 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 is a view of sustainability as necessary in guiding multiple and major change processes in the coming decades. 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).

The substance of sustainability has changed in conjunction with various understandings of the relationship between humans, nature and the economy. These three elements are commonly associated with the social, environmental and economic pillars of sustainability (Waas et al., 2011). In relation to "what" of sustainability, debates have differed between strong and weak sustainability depending on how one is 'allowed' to substitute between capital[3] (Daly, 1990; Solow, 1993). Over time, the discursive level experienced the inclusion of plural factors that extend beyond the environmental realm, including a nuanced interplay of human/nature systems, heightened recognition of the social, appreciation and expansion of human-needs and well-being (Holmberg & Larsson, 2018; Max-Neef et al., 1989) and the growth in local "implementation" and multi-level governance (Hooghe & Marks, 2003; Jacobs, 1999; United Nations, 2015). Similarly, it has seen the involvement of broader perspectives, moving from environmental protection to encompass equity, justice and well-being (Sneddon et al., 2006). Recently, the conversation around sustainability is commonly reduced to that of climate change (Hulme, 2011) and marked by reactionary approaches such as resilience that respond to the various dimensions of sustainability by adapting to impacts (Loring, 2020; Olsson et al., 2015).

Various understandings of sustainability have a role to play in how sustainability is contested and governed. 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 rises up the agenda at the level of cities, regions and countries, the dominant response – techno-fixes and financial instruments – persists, legitimized by the language of planetary governance (Blühdorn & Welsh, 2007; de Vries, 2019). This stems in part from previous narratives concerned with the depletion and substitutability

[3] 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.

of capital (Daly, 1990; Solow, 1993), and more recently to grand scientific frameworks such as the planetary boundaries concept (Rockström et al., 2009). Linked to the latter is an egalitarian and contextual understanding of the environmental, social and economic challenges faced by society in particular places and at particular times (Sneddon et al., 2006; Stirling, 2009a). 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.

2.2.2 Situated sustainability

In debates around sustainability, a situated approach 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 functions as a "socially motivating force, with uncertainties about the end point, but creating conviction for the present" (O'Riordan & Voisey, 1997). Situated engagement with sustainability of this kind is common in modes of reflexive governance such as labs and socio-technical experimentation (Loorbach, 2007; Scholz, 2017). 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)

Situated forms of engagement with sustainability are consistent with recent efforts to rethink science-society relationships in the pursuit of socially robust knowledge towards societal change (Miller et al., 2014). Often called Mode-2, Post-Normal science (Funtowicz & Ravetz, 1993), transdisciplinary (Lang et al., 2012) and knowledge to action (van Kerkhoff & Lebel, 2006), these new approaches belong to a broader post/anti-positivist movement to "focus on 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). These approaches 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). They rest upon the conviction, in various ways, that

"facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz & Ravetz, 1993, p. 20).

2.3 The Laboratory

> For the world to become knowable, it must become a laboratory.
>
> (Latour, 1999, p. 43)

2.3.1 Origins and evolutions of the lab

To many, the laboratory may seem like an odd object of study. They are often portrayed as mundane, sterile, homogeneous scientific spaces. Yet, as a result of the their physical and symbolic development across various scientific periods, the laboratory is 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 as a space within the homes of affluent thinkers and scientific enthusiasts. It was an attempt to carve out a sacred location where external phenomena of the world could be made visible, measurable and knowable (Knorr-Cetina, 1992; Kohler, 2002; Latour, 1983). Within this setting was the attraction that one could generate something, somewhere, under a set of specific conditions that could provide generalizable insights elsewhere (Livingstone, 2003).

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 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). Amidst these changes, the laboratory functioned 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 may have been initially uneven, but they were instrumental in recasting the role of the public to those more familiar binaries within the science community today (van Kerkhoff & Lebel, 2006; Vetter, 2011). Strasser et al. (2018) argues that the combination of science as a profession, and positivism as a unifying approach, necessitated this exclusion:

> …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 in order 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 material, social and political site of scientific praxis (Kohler, 2002). By material, I refer to way in which equipment, objects and infrastructure constitute the material conditions for particular forms of knowledge. By social, I mean the patterns of interaction inside and outside of laboratories, as well as "lab life" as a social and cultural practice (Knorr-Cetina, 1992; Latour, 1983). By political, I refer to the broad historical forces that concentrated and preserve the moral, epistemic authority carried by labs as "truth spots" (Gieryn, 2006; Kohler, 2002):

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 broader 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)

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

More recently, there is a surge in interest in both the scientific and the societal merits of the lab, but for a different reason than before. Labs can now be found not only as sites of scientific generation; they also resemble more open-ended place-based activities where processes of experimentation occur. Their purpose is derived from 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. One the one hand, contradictions 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 enquiry (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 linking to conventional notions of the lab, labs in real-world contexts empathize a more inclusive physical and discursive space where claims to knowledge can 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).

3 Methodology

This section is dedicated to the presentation of my methodological approach to research. Methodology encompasses a range of considerations that extend beyond the choice of methods for a study.

3.1 A qualitative research approach

I take a predominantly qualitative stance in my research. Qualitative research is concerned with understanding human experience and meaning in social life (Bryman, 2012). Over years, the term qualitative research has been positioned in contrast to quantitative research through a number of differences. These include, but are not limited to, research design, relation to data, movement between data and theory, as well as forms of analysis. Qualitative research is typically driven by 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). It is also underpinned by a conception of researchers as embedded within naturalistic settings, rather than as disconnected and objective observers. The differences highlighted above are not merely procedural, informing a different series of steps to be taken in research. They reflect a host of fundamentally different ontological (concerned with the nature of reality), epistemological (concerned with the nature of knowledge) and axiological (concerned with the nature of values) positions (Ross & Mitchell, 2018) associated with a qualitative approach. Given these differences, there is naturally a growing interest in assessing the unique nature of qualitative research. For example, Tracy (2010) claims that high quality qualitative research can be achieved through: (a) a worthy topic, (b) rich rigor, (c) sincerity, (d) credibility, (e) resonance, (f) a significant contribution, (g) ethics, and (h) meaningful coherence[4].

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). In my research, I adopt what may be referred to as a qualitative-dominant approach to research:

> Qualitative dominant mixed methods research is the type of mixed research in which one relies on a qualitative, constructivist-poststructuralist-critical view of the research process, while concurrently

[4] See Tracy (2010) for a substantiated description of quality criteria from a qualitative standpoint.

> recognizing that the addition of quantitative data and approaches are likely to benefit most research projects.
>
> (Johnson et al., 2007, p. 124)

Concretely, I rely on quantitative aspects of a systematic review process, in order to selectively refine a large database of studies to a specific sample of labs. I also adopt a partially quantitative approach in fulfilling RQ1a as a descriptive analysis of the sample of sustainability-oriented labs. I do this as I view this form of analysis to be complementary to the understanding of labs that are required by my research approach. Aside from these choices, my central research design, empirical and analytical choices and data analysis are of a qualitative nature. In addition, I adhere to views on quality that align with qualitative approaches and maintain a reflexive stance in my research and own development that is connected to my philosophy of science.

In qualitative research, the methodology includes the theoretical, method-specific, analytical, procedural and empirical choices that characterise a research approach. Qualitative research can be conceived of as spiralling in its design. A non-linear design acknowledges the often reciprocal and iterative nature of such research, where the researcher moves in a continuous manner between ideas, theory, design, data collection, analysis and dissemination. Often beginning with a rough idea – an initial spark for curiosity and inspiration – spiralling research entails both incremental steps (Figure 2) between data collection and analysis (Yin, 2011), as well those that may lead to the redefinition of a research question or reframing of a research focus. In this thesis my initial spark was an early empirical and analytical interest in better understanding the phenomenon of labs in a way that pays attention to those that connect to sustainability.

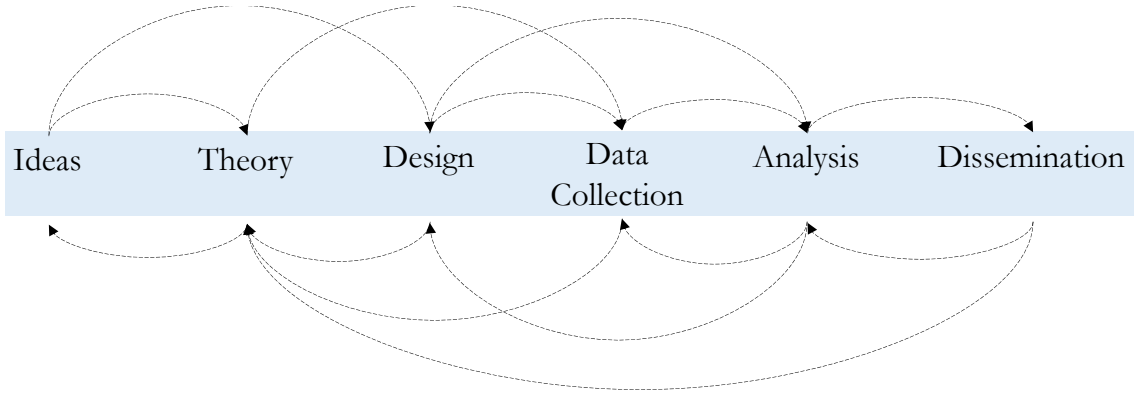


Figure 2: Spiralling research design: Adapted from Berg & Lune, 2017

3.2 A systematic review process

As highlighted in section 1, my research approach includes both a systematic approach to identify labs of relevance and an exploratory approach to investigate their characteristics and defining elements (See table 1).

Systematic reviews include a range of methods and research designs; however, they can be understood through their approach to collecting and/or integrating secondary sources of data. In particular, reviews are systematic when they are protocol-driven and stepwise in their collection of data (Egger et al., 2001; Thomas & Harden, 2008). The systematic nature of a systematic review process is adopted in contrast to a narrative review, often viewed as more subjective and selective in its engagement with literature (Bryman, 2012). The expectation with systematic reviews is then that this data can be engaged with in a variety of ways through a synthesis, where the nature and function of synthesis can differ significantly (Dixon-Woods et al., 2006).

Once viewed exclusively as a more positivist and aggregative setup, the term systematic review now encompasses an array of quantitative, qualitative and mixed approaches to synthesis (Bryman, 2012; Grant & Booth, 2009). Qualitative systematic reviews, whilst relatively new in comparison to conventional systematic reviews, can be organized differently depending on the nature of the object under study and the function of the review (Macura et al., 2019; Thomas & Harden, 2008). They explicitly attempt to incorporate various forms of evidence, previously labelled as subjective and of low-quality, into review processes (Dixon-Woods et al., 2006). By focusing specifically on qualitative sources of data, "qualitative procedures seek patterns among cases, but do not reduce these cases to their averages" (Berg & Lune, 2017, p. 15).

In this sense, the qualitative systematic review is profound in its epistemological implications for understanding various forms of evidence in decision-making processes. It rejects a purely rationalist prioritization of papers for analysis, in favour of a more plural and inclusive approach to assessing quality (Dixon-Woods et al., 2006). This presents possibilities for systematic reviews to include evidence that is narrative-descriptive, theory-oriented and empirical (Thomas & Harden, 2008). In addition, qualitative systematic reviews reject statistical and bibliometric analysis procedures, in favour of organic, creative and interpretive approaches to synthesis (Greenhalgh et al., 2005).

3.3 Connection to licentiate

With these factors in mind, the approach adopted in this research can be characterised as a systematic review process that is predominantly qualitative in nature. Clark (2016) argues that qualitative systematic reviews encourage research that is both broad and

deep, focusing on specific factors of interest of phenomena of importance. Qualitative systematic reviews are encouraged as they provide a means for generating oversight of a field of research or phenomenon under enquiry, where:

> 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)

Specifically, this thesis is analytically concerned with laboratories in real-world contexts as the guiding object of study, and sustainability as a factor of importance. These labs exist in various contexts and take various forms. Due to their highly interdisciplinary and situated nature, any understanding of these labs is scattered across different disciplines.

This process focused on the identification of labs with an explicit orientation towards sustainability. To collect data relevant for this study – case-specific information regarding various labs – we identified secondary sources using a systematic search string. This search string functioned as a filter, intended to narrow a large unstructured field based on research interests and scope. This can be seen as an overarching strategy for both papers I and II, where the sample of labs collected in paper I underpins the classificatory approach of paper II.

Table 1: Research strategy underpinning papers I and II

Paper / Methodology	Paper 1 (RQ1)	Paper 2 (RQ2)
Purpose of approach	Exploratory	Classificatory
Methodological approach	Systematic review methodology	Empirical typology development
Objects of enquiry	Labs with an explicit orientation towards sustainability	Orientations of labs towards sustainability
Data source	Peer-reviewed articles and book chapters	Sample of labs from review (Paper I)
	Selection of 53 sustainability-oriented labs in real world contexts	Development of empirically grounded typology
Central findings	Identification of 7 discrete conceptualizations of labs	Generation of 6 types of sustainability-oriented labs
	Triadic understanding of labs as spaces, processes and ways of organizing	

4 Summary of appended papers

In this section, I briefly frame and motivate both appended papers that constitute this licentiate thesis.

4.1 Paper I

There are growing claims that meaningfully engaging with complex sustainability challenges requires change of a systemic nature (Köhler et al., 2019; United Nations, 2015). In governing transitions to sustainability, laboratories in real world contexts are growing in presence and promise (Nevens et al., 2013; Schäpke et al., 2018). Yet, they span an array of contexts, conceptualisations and cases, making it difficult to find and relate labs across disciplines. Moreover, it is unclear how these labs vary in their approaches to sustainability, the importance of which has been voiced by the sustainability transitions community. The focus of paper I was to methodologically combine the phenomenon of labs in real world contexts and sustainability guided by the following overarching research question: **How can sustainability-oriented labs in real-world contexts be understood?** This question was approached via three sub questions, aimed at exploring labs at the level of sample (RQ1a), discourse (RQ1b) and practice (RQ1c).

We adopted a systematic review method, capable of allowing a structured collection and analysis of cases from real-world contexts. The scope of this research remained distinctly broad in considering various lab approaches, underpinned by sustainability as an anchoring concept to systematically guide the collection of lab cases. This is reflected in the choice of a broad search string in order to maximize inclusion, a gradual narrowing through the use of exclusion criteria and an inclusive approach to field of research.

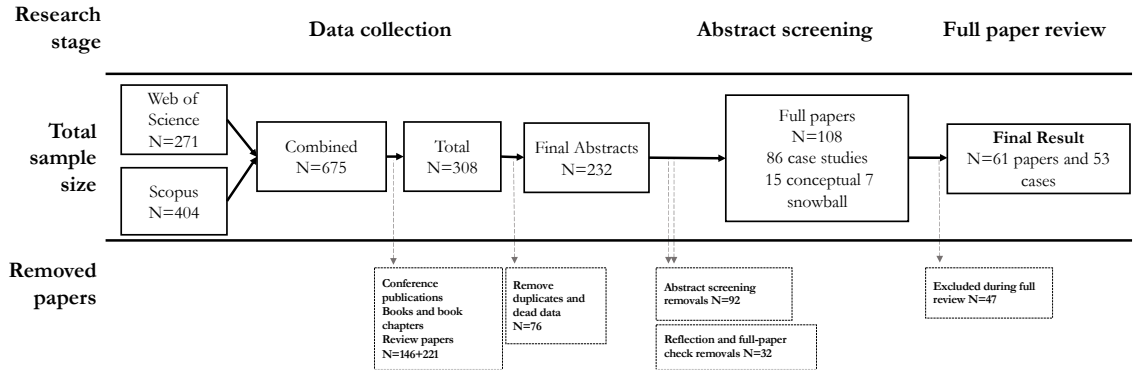


Figure 3: Systematic literature review process for Paper I (McCrory et al., 2020).

4.1.1 Central findings

This paper 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 which conceptualize labs and 3) understanding the characteristics of lab practices (figure 4). Firstly, we provided an overview of the diversity in distribution, thematic focus and setup of labs. Secondly, we traced 7 different research communities where sustainability-oriented labs have been conceptualized (Living, Urban Living, Real-world, Evolutionary Learning, Urban Transition, Change and Transformation labs). Thirdly, we presented a triadic view of labs as of labs as spaces, processes and ways of organising around sustainability challenges.

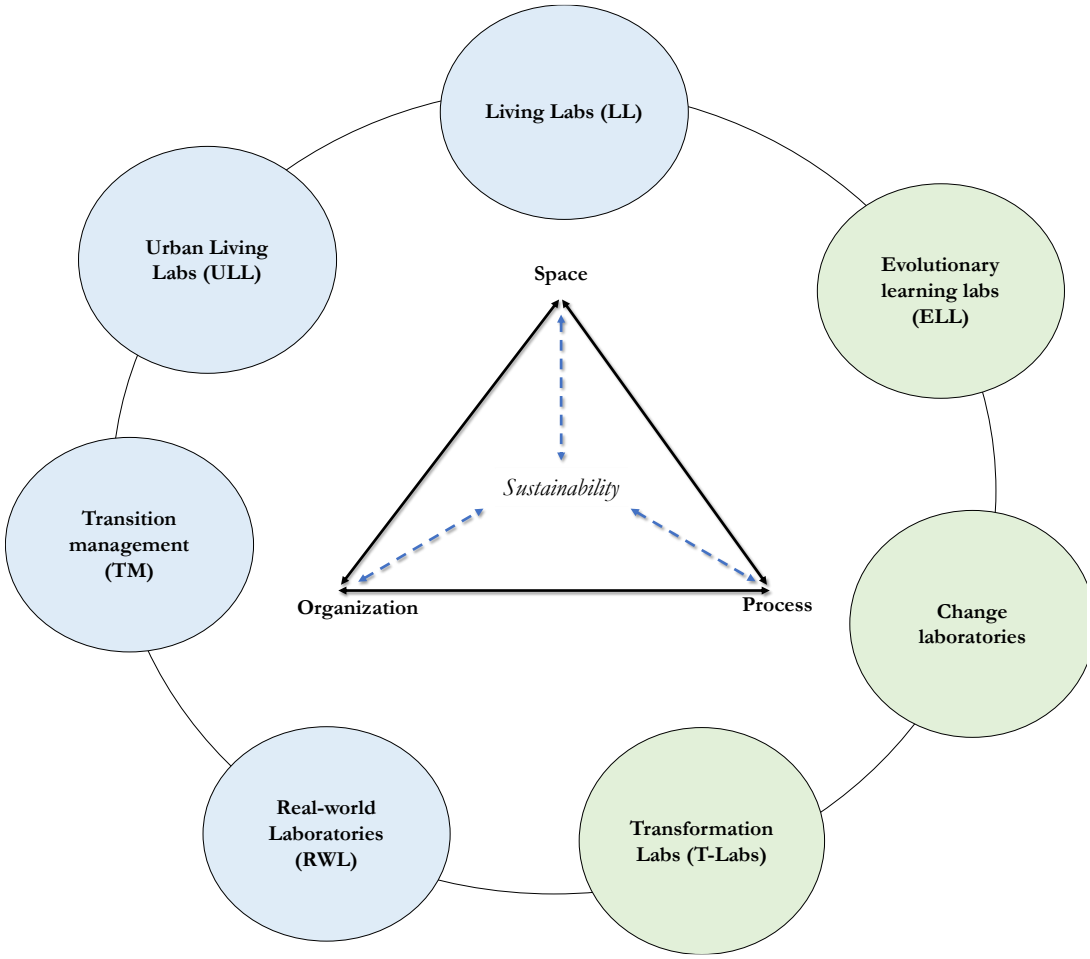


Figure 4: Presentation of results from Paper I. In outer circle are 7 discrete research communities that conceptualize sustainability-oriented labs, both connected (Blue) and unconnected (Green) to sustainability transitions research. In addition, a triadic understanding of labs as spaces, processes and ways of organizing, is presented, where sustainability is seen as a dynamic normative property of labs.

4.2 Paper II

Paper II built upon and extended the insights of paper I by categorizing sustainability-oriented labs in real world according to their various understandings of and approaches to sustainability. It was motivated by the claim, articulated in paper II, 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., 2017; Stirling, 2009). Additionally, the motivation for this paper emerged from paper I, where "for some, sustainability was treated as an exogenous environmental challenge to be solved through particular technological systems. For others, it was treated as a contingent manifestation of a complex, multi-dimensional phenomenon" (McCrory et al., 2020, p. 12). Therefore, we adopted the main research question: **In which ways do sustainability-oriented labs engage with sustainability?**

We adopted a qualitative case-based approach to classify labs according to their properties (Kluge, 2000). Methodologically, we employed a 4-step typology process (presented in figure 5), including the development of dimensions, grouping of cases, analysis of empirical regularities and subsequent construction of types and typology.

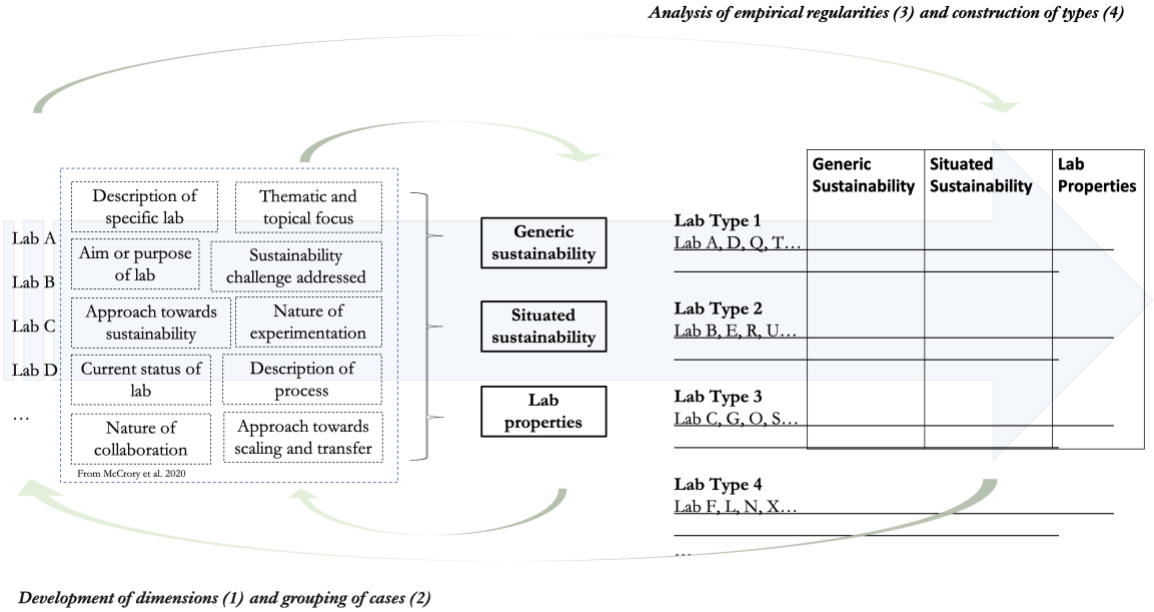


Figure 5: Schematic of typology process adopted in Paper II. Steps 1 and 2 based on the dataset from McCrory et al. (2020). On the left-hand side, we see different labs and associated categories in order to generate categories for lab dimensions. These were analyzed and organized, resulting in the development of three dimensions. This resulted in an iterative move from description of each lab according to types, into a type-based classification.

The process of typology development entails a broad reflexive approach where one assesses an array of material, classifies according to shared descriptors and examines the material in order to remain mutually exclusive (Berg & Lune, 2017). We developed a provisional set of dimensions to support in classification: 1) generic sustainability descriptions, 2) situated sustainability descriptions and 3) a provisional set of properties of sustainability in labs. The central output of analysis takes the form of a typology, 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).

4.2.1 Central findings

Through our analysis, we arrived at 6 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 2 according to their generic and situated sustainability descriptions, and further expanded upon in table 3. They broadly differentiate generic sustainability as a matter of technology, consumption, participation, education, the urban or complex challenges respectively. In addition, they situate sustainability locally as issues of inefficiency, lifestyles, practices, university-society relations, governance and undefined local contexts respectively.

Table 2: Typology of sustainability-oriented labs with generic and situated sustainability description

Lab type	Generic sustainability	Situated sustainability
Fix and control	A technical challenge	Inefficiency at the level of technical systems
(Re-)Design and optimize	Consumption and user involvement in technology	The level of lifestyles and behaviours
Make and relate	Participation in culture, making and organizing	Practices and relations in local communities
Educate and engage	Education for sustainable development	Rethink the relationship between university and society
Empower and govern	Interconnected urban challenges	Regeneration and governance
Explore and shape	Complex, contested, and as a challenge to linear approaches	Often defined as part of local context

The development of 6 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 (horizontal) and across types (vertical). This typology offers explanatory power in inviting a discussion around the diversity that exists across different labs in sustainability transitions, relevant for living processes of classification, informed lab design, and reflexive lab praxis.

Table 3: Typology of sustainability-oriented labs – detailed

Properties / Lab type	Constructed as	Ambitions	Foregrounding	Framing of innovation	Collaboration
Fix and control	Research/private testbeds at city/district level	Technical roll-out	Technology in responding to sustainability	Market-oriented innovation, technology as an end	Instrumental, citizens as receivers
	Closed, research-driven experiments on uni campus	Technical scaling across buildings	Technology in responding to sustainability	Market-oriented innovation, technology as an end	Expert-driven
(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-driven, with tech challenge at starting point	User-focused with hybrid research involvement
Make and relate	Hubs, constructed and bound at the local level	Embedding	Communities, practices and relations	Social innovation	Voluntary and driven by locals
Educate and engage	Educational learning environment	Multi-stakeholder real-world education using TD tools	New ways of educating	Curriculum innovation	Student-stakeholder-society; researcher as teachers
Empower and govern	Urban, partnership-based and inclusive	New ways of governing and organizing around community challenges	Partnerships and governance	Technology as means; innovation as participatory	Driven by communities/ researchers
Explore and shape	A shared exploration	Grasping complexity	Methods and process	Systemic - opening boundaries within which innovation may occur	A pre-condition, with researchers as process designers

5 Discussion

In this section, I turn to a discussion of the findings in the context of my research questions. In addition, I reflect upon the methodological limitations of my work to date and point towards both shaping factors and concrete avenues for future research.

5.1 Situating my research contributions

As established in section 1, the purpose of this thesis is to establish a normative understanding of laboratories in real-world contexts through the use of sustainability as an organizing concept. I achieve this through the adoption of one interconnected research strategy – a systematic review process – organized around two research question and associated sub-questions:

1. **How can sustainability-oriented labs in real-world contexts be understood?**
    a. How are sustainability-oriented labs distinguishable at a sample level?
    b. Which research communities are connected to sustainability-oriented labs?
    c. How can lab practices be characterised in relation to sustainability?
2. **In which ways do sustainability-oriented labs engage with sustainability?**
    a. Which similarities and differences can be observed amongst sustainability-oriented lab in how they engage with sustainability?

In fulfilling these research questions, this thesis contributes to existing empirical, methodological and conceptual knowledge by:

Highlighting the rich landscape within which sustainability-oriented labs currently exist (Empirical: RQ1a&b, Paper I)

In relation to research question 1, I integrate knowledge on sustainability-oriented labs from various areas of application, research communities and cases. The studies included in this licentiate generate a cross-field understanding of 53 different labs, from seven different research communities, that have an orientation towards sustainability. This approach supplements existing collections of labs that often focused on a specific concept, field of research or thematic area.

Focusing on labs that hold an explicit orientation towards sustainability (Empirical: RQ1a, Paper I; RQ2, Paper 2)

The findings from both papers contribute to the empirical understanding of labs by specifying a collection of labs that are explicitly oriented towards sustainability. Rather than focusing on particular 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 insights. We held an interest in generating knowledge that can allow for conversations both between research and practice, as well as fields concerned with sustainable transformation and transition.

Providing an overview of theoretical engagements that are currently visible (Conceptual: RQIb&c, Paper I)

Rather than limiting to within specific fields of discipline or conceptualizations – a common methodological choice made in other studies of relevance (Hossain et al., 2019; Schäpke et al., 2018) – I identify, unpack and further comprehend 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). This point of contact can be seen by some as a source of tension, where competing views may meet. Alternatively, I view this as a space where paradigmatic differences can be discerned, allowing those involved in understanding, designing or critically investigating labs to better comprehend 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 1, 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).

Nuancing the conversation around sustainability in labs (Empirical and conceptual: RQ1c, Paper 1; RQ2, Paper 2)

Despite a view that these labs share a commitment towards sustainability, I was interested in how these commitments are embedded differently into the design and ambitions of labs. In paper I, I present labs as a combination of space, process and organization, a characterization of lab practices specific to those oriented around sustainability. I establish sustainability as a dynamic normative property in labs; a property that that is broadly shared across all cases but is interpreted in different ways in each context. This finding established the basis for a deeper comparative approach,

knowing that there is a need to question the goal-based nature of these initiatives given their different designs, conceptualizations and contexts.

Highlighting how various labs compare and relate to each other in practice (Empirical: RQ1c, Paper 1: RQ2, Paper 2)

The empirically grounded typology, developed in paper II, functions as a way of distinguishing levels of sustainability as a generic matter of concern and as a practically emergent and situated element. Through the development of six types, it is possible to distinguish groups of initiatives 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)**.

Interestingly, the distinctions raised above resonate with sustainability transitions discussions that attempt to further articulate how labs relate to change processes. They relate to the means vs 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. This typology and its associated dimensions provides 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.

Contributing to the methodological development of systematic review processes that are qualitative in nature (Methodological, RQ1&2, Paper 1&2)

As mentioned above, these contributions are both empirical and conceptual. However, this approach also represents a methodological attempt to conduct a systematic review process in an exploratory fashion. In this case, research questions served as a provisional anchor for data collection (Dixon-Woods et al., 2006). In addition, this licentiate and both papers dedicate significant space for reflecting upon the methodological choices made and their limitations. This is a deliberate choice made, in an effort to make visible the lived reality and practice 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 licentiate contributes to more recent studies in this field that have attempted to advance transition knowledge through the systematic review, including topics such as 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 these reviews 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 design in this licentiate is unique in that it combines 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.

5.2 Future research avenues

In this section, I point towards possible links to the research within this thesis, as well as lines of development that extend beyond, yet complement, my current focus. Additionally, I reflect on the factors that shape future research post-licentiate.

For some students, the remaining years of the PhD seem relatively set-in stone. All that remains is to follow the path and stick to the timeline. For others, the future of the PhD is shrouded in opportunity and mystery, to be decided upon after the licentiate. It is a space where one can speculate about, define or simply give shape to possibilities that lie ahead. Either way, whether singular or plural, how I reason about the future of my work here is in some way performative in "establishing the presence of 'what has not happened and may never happen" (Massumi, 2007). The trajectory that I choose to continue with is inevitably one where my aspirations, expectations and conditions converge. The choice is not necessarily self-evident or straightforward. It is a matter of values, curiosity, concern, agency and hope.

The future of my research remains in the process of development. Nevertheless, I foresee four different sources where they may be shaped:

5.2.1 Avenues that stem naturally from the contributions of this thesis

As mentioned in section 3, a qualitative review process established a level of oversight into a field or object of interest. In the case of my thesis, I have been interested specifically in sustainability-oriented labs in real-world contexts, and the particularities of sustainability in theory and practice. Contemporary research on labs and alternative forms of experimentation are often practical in their scope and interests. As such they seek not solely to understand how labs unfold, but to also design and participate in labs as multi-stakeholder collaborations.

Comparative development of typology of labs

The typology in paper II presents a classification space that can inform the design of future labs based on a plurality of ambitions and orientations. In addition, the frame provided is capable of provoking one to reassess and re-evaluate the direction of change implied in a particular design. As highlighted in figure 6, the six lab types may provide a basis for mapping types according to their properties. By focusing on the nature of the sustainability challenges (in terms of their dimensions and level/nature of definition), such an approach may further highlight the spectrum between sustainability as narrow, fixed and immediately solvable, and sustainability as multi-dimensional, subject to definition and with both problem and solution uncertainty.

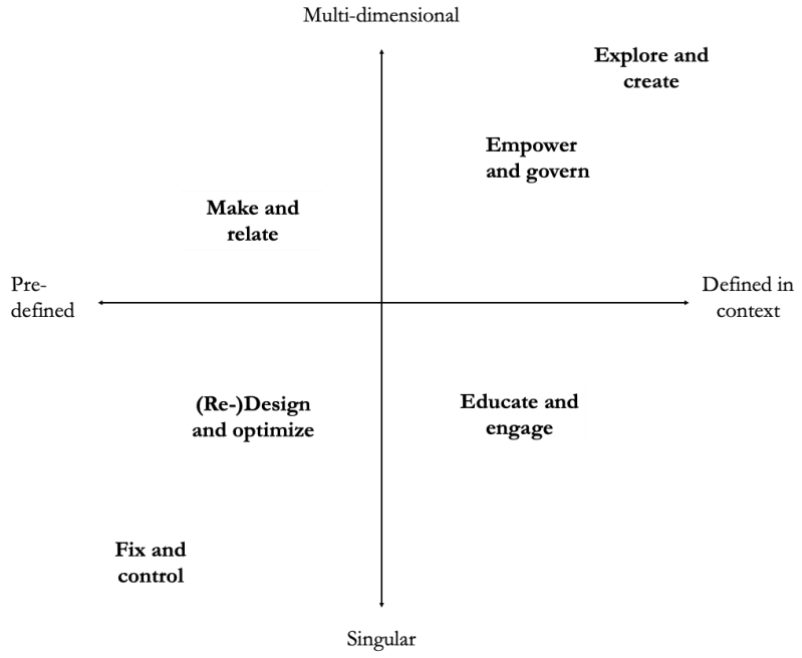


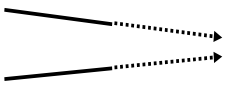
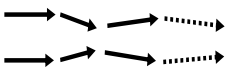
Figure 6: Mapping sustainability-oriented labs based on their engagement with sustainability. On the X axis lies a spectrum in how processes of defining what sustainability is take place in labs, ranging from pre-defining what sustainability is, to full defining sustainability in context. The understanding of sustainability challenges – ranging from singular to multiple and multi-dimensional – can be seen on the Y axis.

Linking with reflexive governance

The work of Voss & Kemp (2005) provides a means to delineate various strategies for reflexively governing processes of transitional change. The authors suggest to "balance the opening-up of governance processes for incorporating uncertainty, ambivalence and distributed control with closing-down governance processes in order to be able to decide and take action" (p. 24). The authors present a variety of distinctions that may be helpful in extending our understanding of how current labs align with various views of reflexive governance (see Table 4). The extension in table 4 illustrates how problem complexity, problem definition, nature of process, solution/strategy definition are arranged in the context of the types developed in paper II.

By drawing on reflexive governance, it becomes possible to explore the ways in which political transitions interactions are catered for in different labs. If regarded as the capacity for continuous societal reflection (Meadowcroft, 2009), it stands to reason that labs are sites where "battles for meaning" (Jacobs, 1999) take place in the context of sustainability. Of equal importance to labs that broaden, unfix and open up sustainability challenges are those who narrow, rigidly define and close down conversations about what sustainability is, could be and should be. Therefore, the function and nature of this meaning-making affect the expected direction of labs, the normative goals and the situated views of sustainability in place.

Table 4: Lab types as reflexive governance (adapted from Voss and Kemp, 2005)

Lab types	Problem - solution	Description
Fix and Control		Narrow challenges and solutions are pre-framed unless reframed by experts. Expert-driven and implementation-focused. Instrumental/extractive participation.
(Re-)Design and optimize		Narrow, pre-defined sustainability challenge or solution, opening up and closing down process. Solution form known in advance to some extent with prototype expected. Directed participation to achieve particular ends.
Empower and Govern; Educate and Engage		Pre-defined sustainability challenge, opening up to incorporate either different elements of sustainability or perspectives. Negotiation generally within certain limits.
Empower and Govern		Multi-dimensional sustainability challenges. Emphasising complexity and scale of issue. Yet, need to close down and concretely move forward. Some solution definition, but eventual form less known in advance
Educate and Engage; Explore and shape		Bundle of sustainability challenges with high problem/solution uncertainty. Emphasises plurality and space, intrinsic processes, learning, discovery. Heterogeneous actor groups vital to collective exploration

5.2.2 Two overlapping areas of interest for future research

In pointing towards more likely avenues for research, I organize around two areas that I have an interest in connecting to. These two developments necessitate research of a different nature than in the first half of this PhD but remain tightly linked with my philosophy of science and methodological interests. They can generally be characterized by a movement towards theoretical and empirical engagement associated with labs with an interest in perspectives on learning.

Conceptual engagement with labs as 'learning spaces'

Of particular relevance here is the broad assertion of learning as necessary in sustainability transitions (van Mierlo & Beers, 2018; Van Poeck et al., 2018). Conceptualizations of learning can be seen as coming from 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) and social/reflexive governance literature (Collins & Ison, 2009; Voss & Kemp, 2005). Within this context labs are often referred to as "niches" (especially Living and Urban Living Labs). Additionally, they are now also being mobilized strategically by city and regional actors as new opportunities to explore unchartered territory, by providing space to test and learn in real-world contexts (Bulkeley et al., 2016). Labs are often described as experiential interventions, accommodating learning by doing and doing by learning. Recent work has attempted to actively engage with learning analytically in understanding labs (Larsson & Holmberg, 2018; McCrory, 2016; Singer-Brodowski et al., 2018; Wanner et al., 2018). Whilst present in debates around labs, learning has been engaged with thinly across theories and concepts.

Moving forward, the purpose of my research is to frame and explore labs using learning as a theoretical lens. It aims to do this by drawing upon both educational geography and spatial theory in order to establish the conceptual relevance of labs as certain kinds of learning spaces (Leander et al., 2010; Temple, 2008; Thomas, 2010). These two fields of research intersect around themes such as mobilities of learning, which explores when and where researchers and participants expect learning to take place (Leander et al., 2010). Spatial theory provides a complimentary perspective by directing attention to a more spatially informed ontology, emphasising the various ways in which space can be understood and unpacked (Borch, 2002; Brenner, 2000; Merrifield, 1999). Spatial theory brings with it a nuanced understanding of space as material, perceived and conceived (Lefebvre & Nicholson-Smith, 1991). By assuming a spatially explicit approach with an orientation towards learning, it may become possible to explore labs as socio-spatially constructed, layered, contingent and negotiating. Spaces such as labs can thus be viewed as simultaneously produced and reproduced through social relations (Bonnett, 2003).

Empirical case-based engagement informed by learning theory

Connected to the interest in embedding learning into my PhD, future research will also be of an empirical, case-based nature.

The Goldmine: Exploring processes of learning in an Urban Living Lab

In an ongoing study originally developed in 2016, I adopt qualitative methods as part of a case-based research strategy. Empirically, I draw on the Goldmine, a lab in Copenhagen organized around urban waste challenges. It represents an "experimental" prototype, in the form of a waste recycling station that intends to foster practices of circular economy through innovation.

Methodologically, data was collected by interviews and complemented with various sources so as to allow findings that converge. I harness multiple documents, literature and additional interviews, structured around an exploratory qualitative case study approach. I will focus my attention on the multiple actors that inhabit the lab during a 2-year experimental period, connecting their experiences, motivations and ambitions to the conditions within which the Goldmine is situated.

Learning to frame complex sustainability challenges: A case study in higher education

Secondly, I turn to the topic of education for sustainable development. Education for sustainable development (ESD) holds an ambition to address sustainability challenges in society with and through transformative modes of education, where students are expected to both unravel the complexities of sustainability, and develop agency in taking action (UNESCO, 2014). ESD includes a series of situated learning approaches, occurring in-between educational and societal institutions with an ambition of transformation. Such approaches commonly depart from well-structured problems that entail expected solutions, towards ill-structured or ill-defined problems that are characterised by wickedness (Ness, 2020; Pearce & Ejderyan, 2020; Rittel & Webber, 1973). These are often organized as problem-based teaching approaches, as well as challenge driven curriculum.

In future research, I aim to explore how a challenge-driven approach to complex sustainability issues can be structured from an educational perspective, and how it is experienced by students from a learning perspective. Learning here is conceived of as extending beyond individual cognition, and as a socially constituted process whereby elements of participation and becoming are fundamental. It is situated and relational (Wenger, 2010), occurring not through processes of internalization – that is; not to be acquired – but rather, as mediated by a nexus of social interactions and tools (Leander et al., 2010; Sfard, 1998).

Conceptual and empirical research of this kind connects to ongoing debates on geographies of transitions (Hansen & Coenen, 2015; Longhurst, 2015; Raven et al., 2012; Smith & Raven, 2012), a burgeoning strand within the transitions community whose point of departure is that:

> transitions are shaped both by the ways in which socio-technical systems are embedded in particular territorial contexts, and by the multi-scalar relationships linking their heterogeneous elements to actors, materials, and forces situated or emanating from different locations or scales.
>
> (Murphy, 2015, p. 75)

5.2.3 Avenues that have emerged during the first three years of my PhD

The life of a doctoral candidate is much more than research. In my case, the papers that I have published, and associated research, comprise one of three formal activities in my doctoral journey. My research has been additionally shaped continuously by departmental activities, predominantly in the form of teaching, and the courses that I take as a student.

With regards to teaching, I dedicate most of my time and resources across various activities within Challenge Lab. This 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). In Challenge Lab, I have learned continuously and had the opportunity to develop alongside ambitious students who are seeking to become agents of change for a more sustainable society. I have sharpened my own research skills through engagement with academic writing, transitions theory, systems thinking, backcasting as an overarching approach. Here, I have also experienced the appeal in and power of values and principles-based approaches to education for sustainable development, leading to some profound encounters with students, stakeholders and researchers who voluntarily organize around complex sustainability challenges.

As such, Challenge Lab provides a fertile transdisciplinary space to naturally connect research with practice, and knowledge with action. I see my departmental responsibilities as inseparable from my own development, and the knowledge generated in Challenge Lab to be directly relevant in shaping my research interests. A majority of my intellectual and practical exchanges take place in this space, as part of a research group central to the development of Challenge 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 transdisciplinary approaches (Brandt et al., 2013; Kagan, 2019).

5.2.4 Avenues that remain to be uncovered

Despite what is more known at this point in my journey, it is worth mentioning the less known or unforeseeable. 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. Firstly, these may include future events of a nature that pique my interest, shift or disrupt my inner compass, or whose engagement with is of deep personal and societal significance. 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 Chicage Heatwave of 1995:

> My trip home initially left me even more puzzled by the heat wave and the processes through which we have come to know it. There was an urgent need to conduct what I imagined as a social autopsy, yet the concept of such an undertaking—let alone a technique for performing it—did not exist […] I initiated the research for what became a five-year examination, and the report before you recounts what I found.
>
> (Klinenberg, 2015, p. 13)

Secondly, future research may arise out of chance encounters or windows of opportunity. The former may emerge from any number of social interactions that are to take place in the next few years. The latter may include funding calls yet to be announced, conferences yet to be attended, vacancies yet to be posted, journal special issues yet to be published, meetings yet to be scheduled, and so on and so forth. Both chance and opportunity may not only affect the cultivation of new research ideas, but their existence will likely give shape to existing ideas and research designs. Thirdly, as research is social and relational, there are countless interactions that may influence the research that I engage in. These can range from a minor exchange, exposure to an unfamiliar concept or a moment of collaborative inspiration. Given that such future moments may or may not ever come to be, this section is essentially anticipatory in character. It provides a basis for reflection and may serve as a healthy reminder that research can come about in serendipitous fashion.

5.3 Limitations and considerations

In section 5.1, I focused on motivating and outlining the way in which my licentiate contributes towards pre-existing knowledge within my field. Alongside the various claims that I make, are a number of limitations to my research to date.

Firstly, the data underpinning this research is derived from secondary sources. I rely on peer-reviewed articles, as well as selected books, to say "something" about the phenomenon of labs. I 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 have been both encouraged (Clark, 2016) and criticized (Dixon-Woods et al., 2006). In engaging with labs as my object of study and relying on secondary sources, my research strategy involves a triple movement of interpretation. Triple interpretations occur when the process of synthesising involves a collection of complex qualitative cases into a sample. Here, I am mindful of the inability to "have a full understanding or appreciation of the context in which the research interactions take place" (Weed, 2005).

Despite this limitation, triple interpretation was both expected and grappled with during studies I and II. Methodologically, we attempted to maintain a transparent and reflexive approach during the systematic review process (Weed, 2005), 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 frequent 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 decontextualization of findings becomes more likely. At the same time, the intention of a qualitative review process differs from those that accumulate knowledge on a specific topic. Instead, my goal has been to reach new levels of meaning or patterns that are only possible through triple interpretation, whilst remaining humble about the limitations of this.

Secondly, the ambition of this study was to direct more attention towards notions of sustainability that are present in labs in real-world contexts. As highlighted above, papers I and II 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 and differ 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, I recognize that sustainability is 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. Therefore, this licentiate attempts to say something about sustainability in the context of a systematic review process, whilst acknowledging that extensive research approaches may be required to investigate the dynamics of sustainability through process. As mentioned in 5.2.2, my ambition is to engage with notions of learning in order to shed light on how complex sustainability challenges are framed and experienced in the pursuit of transitional change.

6 Conclusion

Outlined within this thesis is an attempt to identify and classify labs in real-world contexts that express an explicit orientation towards sustainability. Methodologically, I present one interconnected qualitative research strategy, a systematic, case-oriented review process. This overall research strategy yielded two specific paper contributions. In paper I (RQ1), I systematically locate and unpack a sample of labs that explicitly connect to sustainability in real-world contexts. Paper II builds upon and extends these insights by classifying labs according to their particular engagements with sustainability.

Within this thesis, I generate knowledge claims regarding a specific collection of sustainability-oriented labs that intersect various disciplines and areas of application. I derive seven different research communities where sustainability-oriented labs in real-world contexts are emerging. I present an empirically grounded typology of labs according to their engagement with sustainability as a generic matter of concern, substantiated in place. Within this typology, I illuminate the similarities and differences within and across six types.

This thesis is aimed towards a relatively broad base of stakeholders engaged in transitions towards sustainability. Whether academics, practitioners or pracademics my hope is that it appeals to those who share an interest in further informing and designing transitional processes towards sustainability. In further complementing the insights from this research, I intend to conceptually adopt learning as a lens for relating to sustainability-oriented labs in real-world contexts. In addition, studies will have a qualitative case-based focus, enabling a contextual understanding of lab processes in practice.

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

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.

Andersson, C. (2014). Complexity science and sustainability transitions. *Environmental Innovation and Societal Transitions*, *11*, 50–53. https://doi.org/10.1016/j.eist.2014.03.001

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

Barnacle, R. (2005). Research education ontologies: Exploring doctoral becoming. *Higher Education Research & Development*, *24*(2), 179–188. https://doi.org/10.1080/07294360500062995

Barry, A., & Born, G. (2013). *Interdisciplinarity: Reconfigurations of the social and natural sciences*. Routledge.

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.

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

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

Berg, B. L., & Lune, H. (2017). *Qualitative research methods for the social sciences* (Ninth edition). Pearson.

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. (2013). *A realist theory of science*. Routledge.

Bhaskar, R., Collier, A., Lawson, T., & Norrie, A. (1998). Critical realism. *Proceedings of the Standing Conference on Realism and Human Sciences, Bristol, UK*, *4*.

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

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-Ohlenschlager, S. J. M. van den. (2010). *Transition experiments: Exploring societal changes towards sustainability*. Erasmus Univ.

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

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

Bryman, A. (2012). *Social research methods* (4th ed). Oxford University Press.

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

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

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

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

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

Daly, H. E. (1990). Toward some operational principles of sustainable development. *Ecological Economics*, *2*(1), 1–6.

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

Dryzek, J. S. (2013). *The politics of the earth: Environmental discourses* (Third edition). Oxford University Press.

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

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

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

Evans, J. P. M., Karvonen, A., & Raven, R. (Eds.). (2016). *The experimental city*. Routledge, Taylor & Francis Group.

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

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

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

Freire, P. (2000). *Pedagogy of freedom: Ethics, democracy, and civic courage*. Rowman & Littlefield Publishers.

Frick, B. (2010). *Creativity in doctoral education: Conceptualising the original contribution*.

Funtowicz, S. O., & Ravetz, J. R. (1993). Science for the post-normal age. *Futures*, *25*(7), 739–755.

Geels, F. W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. *Theory, Culture & Society*, *31*(5), 21–40. https://doi.org/10.1177/0263276414531627

Geels, Frank W. (2002). Technological transitions as evolutionary reconfiguration processes: A multi-level perspective and a case-study. *Research Policy*, *31*(8–9), 1257–1274.

Geels, Frank 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

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

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

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

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., 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

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

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

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.

Hooghe, L., & Marks, G. (2003). Unraveling the central state, but how? Types of multi-level governance. *American Political Science Review*, *97*(2), 233–243.

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

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

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

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.

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

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

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

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

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. (1992). *The couch, the cathedral, and the laboratory: On the relationship between experiment and laboratory in science*. 14.

Knorr-Cetina, K. D. (1981). *The micro-sociological challenge of macro-sociology: Towards a reconstruction of social theory and methodology*.

Köhler, J., Geels, F., Kern, F., Onsongo, E., & Wieczorek, A. (2017). *A research agenda for the Sustaina-bility Transitions Research Network*.

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

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

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., & 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

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

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

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.

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. (2007). *Transition management: New mode of governance for sustainable development = Transitiemanagement: nieuwe vorm van governance voor duurzame ontwikkeling*. Internat. Books.

Loorbach, D., Frantzeskaki, N., & Avelino, F. (2017). Sustainability transitions research: Transforming science and practice for societal change. *Annual Review of Environment and Resources*, *42*.

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

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

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

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

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).

Max-Neef, M., Elizalde, A., & Hopenhyan, M. (1989). Human Scale Development: Development Dialogue. *Dag Hammarskjold*.

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

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

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. (2003). *SCIENCE AS SYSTEMIC INTERVENTION: SOME IMPLICATIONS OF SYSTEMS THINKING AND COMPLEXITY FOR THE PHILOSOPHY OF SCIENCE*. 24.

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

Mingers, J. (2014). *Systems thinking, critical realism and philosophy: A confluence of ideas*. Routledge.

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

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

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

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.

O'Riordan, T., & Voisey, H. (1997). The political economy of sustainable development. *Environmental Politics*, *6*(1), 1–23. https://doi.org/10.1080/09644019708414309

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

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

Piotrowski, M. (2017). Writing in Cramped Spaces. *Reconceptualizing Educational Research Methodology*, *8*(3). https://doi.org/10.7577/rerm.2552

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.

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

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. (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

Rittel, H. W., & Webber, M. M. (1973). Planning problems are wicked. *Polity*, *4*(155), e169.

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. (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.

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

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

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

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

Scoones, I., Newell, P., & Leach, M. (2015). The politics of green transformations. In *The Politics of Green Transformations* (pp. 19–42). Routledge.

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.

Shelley, M. (2012). *Frankenstein*. Broadview Press.

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. (2005a). The governance of sustainable socio-technical transitions. *Research Policy*, *34*(10), 1491–1510. https://doi.org/10.1016/j.respol.2005.07.005

Smith, A., Stirling, A., & Berkhout, F. (2005b). 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

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

Solow, R. (1993). *An almost practical step toward sustainability*. 11.

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

Sovacool, B. K., & Hess, D. J. (2017). Ordering theories: Typologies and conceptual frameworks for sociotechnical change. *Social Studies of Science*, *47*(5), 703–750.

Stirling, Andrew. (2009). *Direction, distribution and diversity! Pluralising progress in innovation, sustainability and development*.

Stirling, Andrew. (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, Andy. (2009). *Direction, distribution and diversity! Pluralising progress in innovation, sustainability and development*.

Stirling, Andy. (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

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.

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*.

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, C., & Sandahl, M. (2016). *Learning objectives for a degree of Doctor – activities and assessment*. 5.

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 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 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

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

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

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

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., 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

Wright, E. O. (2010). *Envisioning real utopias* (Vol. 98). Verso London.

Yin, R. K. (2011). *Qualitative research from start to finish*. Guilford Press.

Appendix A: Doctoral becoming

> Unfinishedness is essential to our human condition. Whenever there is life, there is unfinishedness.
>
> (Freire, 2000, p. 52)

For many doctoral licentiates and theses, the focus of attention is on the substantive contributions of the work to date. These contributions are neatly packaged and ordered as a "thesis by publication" (Mason & Merga, 2018) according to stylistic preference, disciplinary convention and expected audience (Sword, 2012). Here, one must take into account what to convey, how it is to be conveyed and who it should be conveyed to. Of course, this written product is an important means to gauge my progress towards an eventual PhD. It serves as a milestone for assessment, marking a logical yet significant point in a doctoral journey where one is compared against a set of learning objectives (Turner & Sandahl, 2016). Under this view, the licentiate can be regarded as (adapted from Frick, 2010):

- A logical half-way point of a PhD that demonstrates doctoral progress
- Demonstration of discipline-specific knowledge and skills
- A standalone piece, comprising prior contributions and claims to knowledge
- A springboard for the second half of a PhD, in preparation for a research trajectory

Yet, as a written contribution and in a similar fashion to both papers appended herein, this licentiate is both product and process (Colyar, 2009; Emig, 1977). It may demonstrate, in some way, "What I have done", enabling me to communicate insights central to my research. However, this piece arguably provides a space to step into my work in a more reflexive and declarative way, as "a means of looking inward, a means of connecting with ourselves" (Colyar, 2009, p. 429). The importance of introspection is often encouraged as a means to challenge neoliberal models 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, it becomes possible to ask, what am I becoming, based on my doctoral experience? What *should* I be becoming?

Doctoral journeys are creative pursuits. Conversations around becoming and doctorateness emphasise the way in which doctoral students, each from various dispositional, cultural, political, disciplinary and social backgrounds, embark on a

journey. They can take a multitude of different forms, with no pre-established blueprint to be applied in advance. They reflect the uniquely uncertain nature of many learning journeys, where what is to be learned is as much a sensibility as it is a subject (Lin & Cranton, 2005). Here, "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).

With regards to identity, scholarly identities are influenced by, amongst other things, disciplinary norms and expectations (Lovitts, 2005). As neophytes in a broad socialization process, "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).

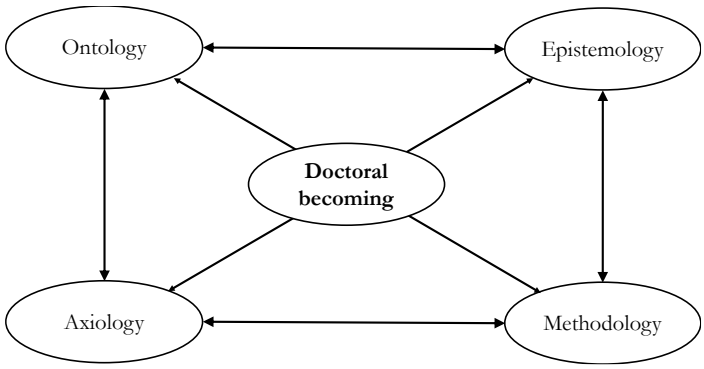


Figure 7: Aspects of doctoral becoming (from Frick, 2010)

Aside from the common competencies that doctoral studies try to foster – knowledge, pedagogical expertise, interpersonal skills, necessary habits – the doctoral journey is one where an ethical sensibility is cultivated. This occurs through the various dilemmas that doctoral students encounter: negotiating authorship (Leonard, 2010), balancing competing responsibilities (Lin & Cranton, 2005), joining a conversation (Piotrowski, 2017) assimilating into an organizational and institutional culture (Frick, 2010).

In looking inwards, I turn to interdisciplinarity and undisciplinary journeys as a helpful frame. I belong to a generation of undisciplinary scholars whose journey is not bound strongly to disciplinary conventions, but rather I share the view that transgressing and connecting across disciplines is key (Haider et al., 2018; Robinson, 2008). Here:

> 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)

As mentioned previously in this thesis, the rise of interdisciplinarity and transdisciplinarity modes of research have disrupted conventional disciplinary claims to knowledge in science. They have done this through the emergence of both academically and societally-driven forms of science that operate outside of or between disciplines (Lyall, 2019). In the context of transformative learning in times of climate change, the uncertainty of the contemporary world require a form of teleological suspension, where the claims to knowledge transgress paradigmatic norms (Lotz-Sisitka et al., 2015). For some, this may require that one deeply questions and unlearns the taken-for-granted assumptions that have carried them through a process of socialization.

In my thesis, I aspire to achieve both a breadth and depth of knowledge that transcends disciplinary boundaries. Although depth of knowledge is of course important, Lyall (2019) argues that an overemphasis on depth and "expertise" has proven problematic as a marker for progress in undisciplinary and interdisciplinary doctoral processes, 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" (p. 2). In addition, she finds that interdisciplinary PhDs experience a host of challenges and 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 or undisciplinary 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. After all, given that institutional cultures are central in developing doctoral identity, how can un/interdisciplinary processes reasonably be navigated?

Rather than narrowing, my research approach is naturally integrative. The reason for this is that, as an un/interdisciplinary scholar, I am driven by real-world phenomena that demand knowledge from between and outside of disciplines. My interest and analytical focus, labs, exist as entities that do not sit neatly within dichotomies such as research or practice, knowledge or action, natural or social science. In un/interdisciplinarity, I adopt a pluralist attitude that requires one to remain epistemically agile and methodologically rigorous when approaching complex challenges. Connected to this thesis, my research has been largely reliant on academic data sources, reflecting a particular form of interdisciplinarity. My goal has been to

connect labs and sustainability across a "field of difference" (Barry & Born, 2013; Thompson Klein, 2010), in a way that disrupts the disciplinary logics that have influenced its development. This was an explicit choice from my side, and one which aims to appeal to a community aligned with an interest through the knowledge generated.

My stance is consistent and complementary to my academic journey to date, which I would summarize as nomadic in nature. With an undergraduate degree in Geography, my understanding of the world was of one full of coupled interactions. Its ontological and epistemological premises are plural, spanning positivist, constructivist to post-modern traditions[5]. My master education was international, interdisciplinary and located within sustainability science, an explicitly normative field of research where those who engage gravitate around a shared problem of societal importance (Jerneck et al., 2011; Kates, 2011). As a smart-cities researcher, I sat within a division of communication sciences interested in citizen-centric collaboration in urban-settings. All three fields of research and practice have informed my thinking, shaped my writing (Piotrowski, 2017) and instilled an interest in me in particular events, theories or developments. Yet, I identify not as a geographer, a sustainability scientist, or a communications scientist. The difficulty of defining oneself only becomes apparent when there is an expectation to be disciplinary.

This licentiate marks a first stage in engaging with labs as real-world phenomena in an undisciplinary manner and grappling with the process of doing so. As such, there is an unfinished and incomplete quality to both my PhD, and my reflections above on becoming.

[5] Although traditionally concerned with physical processes, features and functions, persistent debates around true and false, fact and value and right and wrong had numerous influences on the geographical tradition (Bonnett, 2003). The introduction of both alternative conceptions of the nature of reality - one that might be neither absolute nor necessary – as well as the nature of knowledge in shaping our ideas of this reality, led to noteworthy contributions from Human Geography (initially concerned with the geographies of people, place and space in a material world), Economic Geography (concerned with the spatial flows of people, commodities and capital across boundaries) and what came to be modern geopolitical theory (concerned with the political interactions within different spatially bounded nation states).