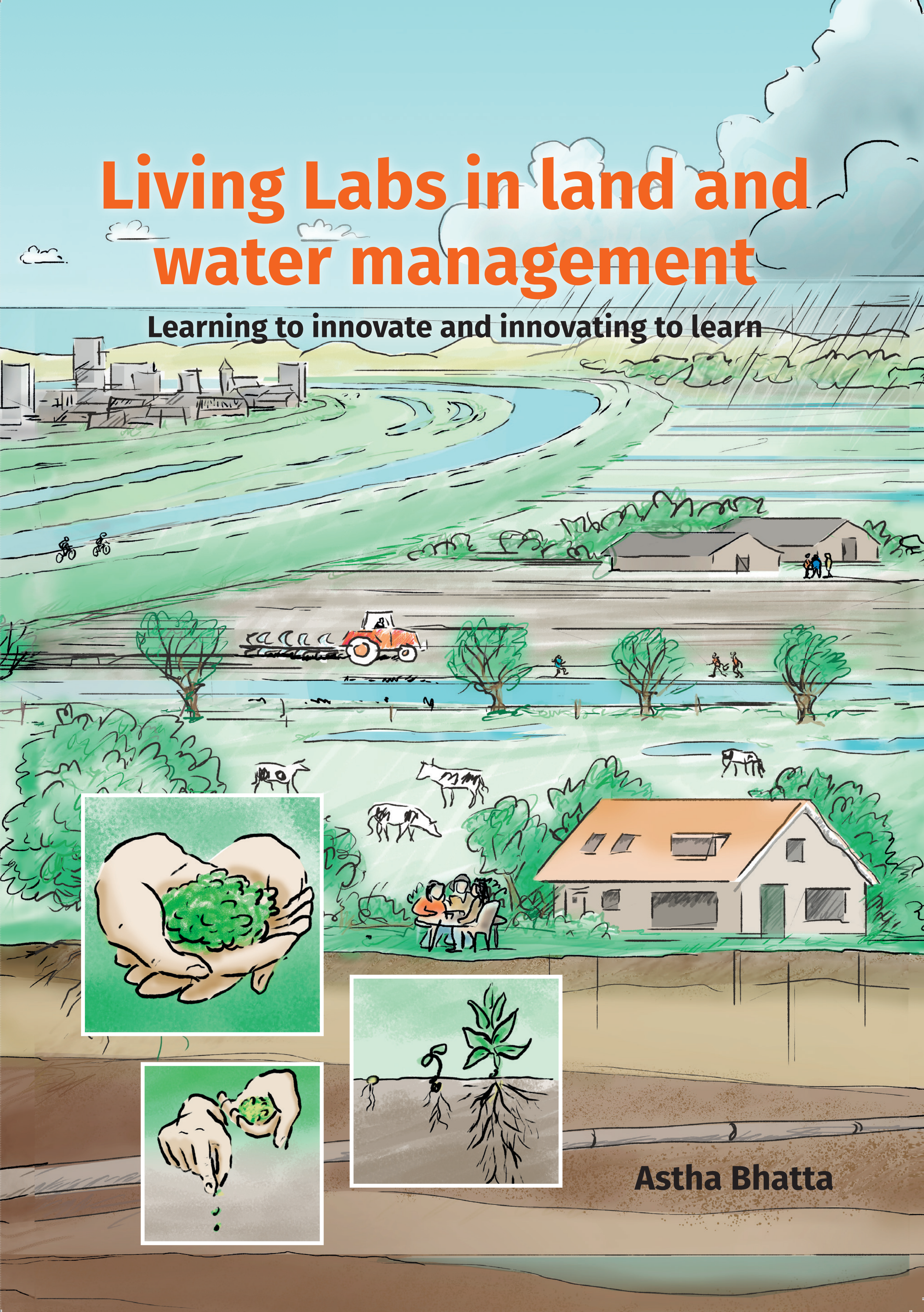
Living Labs in land and water management

Learning to innovate and innovating to learn



Astha Bhatta

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ASTHA BHATTA

LIVING LABS IN LAND AND WATER MANAGEMENT

LEARNING TO INNOVATE AND INNOVATING TO LEARN

Dissertation

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at Delft University of Technology
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by

Astha BHATTA

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

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"This moment feels like a thousand fireflies lighting up the sky. Brief, brilliant, and utterly collective. I believe I am able to be where I am, not as an individual, but as a chorus with so many others."

These words are taken from Banu Mushtaq's acceptance speech upon being awarded the International Booker Prize for her book "Heart Lamp". Even though I wasn't acquainted with her work, her words left such a profound impression on me that I knew this had to become the opening sentence of the acknowledgment of my dissertation. While I see myself as one among many doctoral researchers, far from Mushtaq's extraordinary achievements, her words nevertheless capture the sentiments I carry. Looking back to the last four years of my doctoral journey, the years seem brief in their passing, rigorous in their demands, and entirely collective in their outcomes. Every step forward I have taken, both in completing this dissertation, and in growing as a researcher, is inseparable from the contributions, support, and collaboration of many who have shared this endeavour with me. To all of them, I am deeply indebted.

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Astha Bhatta

SUMMARY

Land and water management operates within complex socio-ecological systems where ecosystems, land uses, and water systems interact to form integrated landscapes. These landscapes face growing anthropogenic and climatic pressures (Haddeland et al., 2014), manifesting as soil degradation, water scarcity, and declining water quality. Addressing such challenges requires integrated innovation strategies that are technically robust, combine ecological integrity with socio-economic viability and prioritize adaptive management. Nature-based solutions (NBS) have emerged as key interventions, offering ecosystem-based approaches that enhance resilience while delivering environmental, social, and economic benefits (de Boer et al., 2019; Faivre et al., 2017). However, successful implementation of these strategies demands more than technical solutions. It requires participatory and collaborative governance models capable of navigating complex institutional, societal, and ecological dimensions (George et al., 2016; Moors, 2017; Weith et al., 2021).

In recent years, the "living lab" approach has gained increasing recognition for its potential to address complex challenges in a participatory and collaborative manner. A living lab is an organized, user-centric approach that drives innovation through co-creation among multiple stakeholders. Despite their growing prominence and widespread adoption, there is a lack of conceptual clarity regarding the core elements of living labs. In living labs, close collaborations between different stakeholders and their networks accelerate the innovation process due to cross- sectoral and disciplinary learning (Edwards-Schachter et al., 2012; Leminen & Westerlund, 2012; Nyström et al., 2014). However, the role of learning in shaping living lab outcomes, and the effects of living labs, particularly in terms of learning outcomes and broader policy influence remains limited. Accordingly, this research aims to advance the understanding of living labs and their effects, particularly within climate-adaptive land and water management.

The research clarifies what constitutes a living lab by first examining the core characteristics of living labs. It then moves on to develop a theoretical framework to conceptualize how learning occurs within the co-creative environments of living labs. Finally, the learning outcomes and policy influence of living labs are investigated. The research employs a mixed-method design, integrating literature reviews and empirical case studies. The adopted literature review methods include snowballing, bibliometric analysis, and systematic review techniques. The empirical analysis focuses on Dutch living labs within climate-adaptive water management, notably the KLIMaat Adaptatie in Praktijk (KLIMAP) case, complemented by three additional cases: Werken met Waterlandschappen (WmW), Self-Supporting River Systems (SSRS), and Schouwen-Duiveland Living Lab (SDLL). Data collection from the case studies involved document analysis, stakeholder interviews, surveys, and participatory observation. The metaphor of plant cultivation is adopted in structuring the research: seeds represent historical foundations, roots signify theoretical grounding, the harvest denotes learning outcomes, and the landscape reflects policy influence.

The existing diversity and ambiguity in conceptualizing living labs is clarified by identifying four core characteristics: (1) real-life settings, where experimentation occurs in authentic environments; (2) pursuit of innovation, focused on creating and testing new solutions; (3) user-centric co-creation; involving active participation of end-users; and (4) multi-actor collaboration, particularly the quadruple helix. The potential variation within these characteristics is recognized, and additional distinctive characteristics of nature-based living labs, such as the focus on sustainability (in the use of materials) are highlighted. These insights provide a conceptual foundation for researchers and practitioners in understanding and operationalizing living labs.

Recognizing that learning during co-creation is underexplored, a novel analytical learning framework was developed, grounded in nine learning theories: behaviorism, cognitivism, constructivism, experimental, situated, social, organizational, transformative, and connective learning theories. The framework enables systematic identification and evaluation of often-overlooked learning outcomes by categorizing learning by type, process, and level. The subcategories include: learning types (content, capacity, network), learning processes (intentional, incidental), and learning levels (individual, team, organizational, systemic). This dynamic framework provides an epistemological basis for living lab learning to capture the often-overlooked learning outcomes, enhancing the strategic value of living labs as co-creative learning environments.

The learning outcomes of the KLIMAP case study were harvested through 'learning pathways' using the learning framework. By systematically tracing seven distinct learning pathways, the research demonstrates how knowledge evolves through co-creative activities and translates into outcomes. The learning pathways are: (1) harnessing collective, integrated knowledge, (2) building collaborative networks, (3) enhancing stakeholder capacity, (4) adapting and contextualizing knowledge, (5) innovation diffusion, (6) facilitating co-creation, and (7) reflecting and learning. These pathways capture both tangible outcomes (prototypes, tested solutions, policy changes) and intangible outcomes (knowledge creation, capacity building, strengthened networks). They enable actors to reflect on collaborative efforts, extract lessons, and apply insights to future initiatives, positioning learning not just as a by-product but as a core component of innovation and impact.

The policy influence of living labs was also investigated. The study offers insights into the current positioning of living labs within different policy phases and highlights the factors enabling this policy influence. Their influence was found to be most pronounced in pre-policy, implementation, and post-policy stages, where they function as boundary infrastructures that facilitate evidence generation, designing interventions, and adaptive governance. However, empirical analysis reveals that their policy impact remains contingent upon enabling factors such as institutional support, stakeholder engagement, focus on learning, high-quality evidence, and integration within broader societal needs and political agenda.

To summarize, the research (i) identified the core characteristics of living labs, (ii) drew on learning theories to develop an analytical living lab learning framework, and (iii) investigated their effects, primarily in terms of their learning outcomes and policy influ-

ences. The focus of this dissertation did not lie on the innovation outcomes of living labs *per se*, but on advancing the understanding of living labs and their effects. Accordingly, it positions living labs as a promising approach for addressing complex, climate-adaptive land and water management challenges. The insights underscore the need for, and the importance of, strengthening living labs as learning-oriented, context-sensitive, and policy-relevant systems that are capable of advancing climate-adaptive land and water management.

SAMENVATTING

Land- en waterbeheer opereert binnen een complexe omgeving van sociaal-ecologische systemen waar ecosystemen, landgebruik en watersystemen samen landschappen vormen. Deze landschappen worden geconfronteerd met toenemende antropogene en klimatologische druk, waaronder bodemdegradatie, waterschaarste en afnemende waterkwaliteit (Haddeland e.a., 2014). Om dergelijke uitdagingen aan te pakken zijn geïntegreerde innovatiestrategieën nodig die technisch robuust zijn, ecologische integriteit combineren met sociaal-economische levensvatbaarheid en prioriteit geven aan adaptief beheer. Op de natuur gebaseerde oplossingen (NBS) zijn hierbij naar voren gekomen als belangrijke interventies. NBS zijn op ecosystemen gebaseerde benaderingen die de veerkracht van het systeem vergroten en tegelijkertijd ecologische, sociale en economische voordelen opleveren (de Boer e.a., 2019; Faivre e.a., 2017). Succesvolle implementatie van dergelijke geïntegreerd innovatiestrategieën vraagt meer dan technische kennis. Het vereist een participatieve en collaboratieve aanpak die in staat is om te navigeren tussen complexe institutionele, maatschappelijke en ecologische dimensies (George e.a., 2016; Moors, 2017; Weith e.a., 2021).

De afgelopen jaren heeft de "living lab-benadering steeds meer erkenning gekregen vanwege het potentieel om complexe uitdagingen op een participatieve en collaboratieve manier aan te pakken. Een living lab is een georganiseerde, gebruikersgerichte benadering die innovatie stimuleert door co-creatie tussen meerdere belanghebbenden. Een living lab versneltsamenwerking tussen verschillende belanghebbenden en hun netwerken, alsook het innovatieproces vanwege cross-sectoraal en interdisciplinair leren (Edwards-Schachter e.a., 2012; Leminen & Westerlund, 2012; Nyström e.a., 2014). Echter, ondanks hun groeiende bekendheid en brede toepassing, is er beperkt conceptueel begrip over de kernelementen van living labs. Bovendien blijven de effecten van living labs beperkt, met namein termen van leerresultaten en bredere beleidsinvloed.. Dit onderzoek is gericht op het vergroten van inzicht in living labs en hun effecten, met name van living labs binnen klimaatadaptief land- en waterbeheer.

Het onderzoek verduidelijkt wat een living lab inhoudt door eerst de kernkenmerken van living labs te onderzoeken. Vervolgens ontwikkelt het een theoretisch kader om te conceptualiseren hoe leren plaatsvindt binnen de co-creatieve omgevingen van living labs. Tot slot worden de leerresultaten en beleidsinvloed van living labs onderzocht. Het onderzoek maakt gebruik van een mixed-method design dat literatuuronderzoek en empirische casestudies integreert. De gebruikte literatuuronderzoeksmethoden omvatten sneeuwbaleffectanalyse, bibliometrische analyse en systematische reviewtechnieken. De empirische analyse richt zich op Nederlandse living labs binnen klimaatadaptief waterbeheer, met name KLIMaatAdaptatie in Praktijk (KLIMAP), aangevuld met drie andere cases: Werken met Waterlandschappen (WmW), Self-Supporting River Systems (SSRS) en Schouwen-Duiveland Living Lab (SDLL). De dataverzameling uit de casestu-

dies bestond uit documentanalyse, interviews met stakeholders, enquêtes en participatieve observatie. De metafoor van plantenteelt is gebruikt bij de structurering van het onderzoek: zaden vertegenwoordigen historische fundamenten, wortels staan voor theoretische onderbouwing, de oogst staat voor leerresultaten en het landschap weerspiegelt beleidsinvloed.

De diversiteit en ambiguïteit van living labs wordt verduidelijkt door vier kernkenmerken te identificeren: (1) real-life settings, waar experimenten plaatsvinden in authentieke omgevingen; (2) streven naar innovatie, gericht op het creëren en testen van nieuwe oplossingen; (3) gebruikersgerichte co-creatie; met actieve participatie van eindgebruikers; en (4) samenwerking tussen meerdere actoren, met name de quadruple helix. Echter, er kan variatie tussen deze kenmerken optreden. NBS living labs kenmerken zich door een focus op duurzaamheid zoals het het gebruik van gebiedseigen materialen en natuurlijke dynamiek. Onderzoekers en mensen uit de praktijk kunnen deze inzichten gebruiken als conceptuele basis voor het inzetten van living labs.

Om leren tijdens co-creatie te duiden is een analytisch leerkader ontwikkeld. Deze is gebaseerd op negen leertheorieën: behaviorisme, cognitivisme, constructivisme, experimentele, gesitueerde, sociale, organisatorische, transformatieve en connectieve leertheorieën. Het kader maakt systematische identificatie en evaluatie van vaak over het hoofd geziene leerresultaten mogelijk door leren te categoriseren op type, proces en niveau. De subcategorieën omvatten: leertypen (inhoud, capaciteit, netwerk), leerprocessen (intentionele, incidentele) en leerniveaus (individueel, team, organisatorisch, systemisch). Dit dynamische kader biedt een epistemologische basis voor living lab-leren om de vaak over het hoofd geziene leerresultaten vast te leggen, waardoor de strategische waarde van living labs als co-creatieve leeromgevingen wordt vergroot.

De leerresultaten van de KLIMAP-casestudy zijn verzameld via 'leerpaden' met behulp van het leerraamwerk. Door systematisch zeven verschillende leerpaden te traceren, laat het onderzoek zien hoe kennis evolueert door co-creatieve activiteiten en zich vertaalt in resultaten. De leerpaden zijn: (1) het benutten van collectieve, geïntegreerde kennis, (2) het opbouwen van collaboratieve netwerken, (3) het versterken van de capaciteit van belanghebbenden, (4) het aanpassen en contextualiseren van kennis, (5) het verspreiden van innovatie, (6) het faciliteren van co-creatie, en (7) reflecteren en leren. Deze paden leggen zowel tastbare resultaten (prototypen, geteste oplossingen, beleidswijzigingen) als immateriële resultaten (kenniscreatie, capaciteitsopbouw, versterkte netwerken) vast. Ze stellen actoren in staat te reflecteren op gezamenlijke inspanningen, lessen te trekken en inzichten toe te passen op toekomstige initiatieven, waardoor leren niet alleen als een bijproduct wordt gepositioneerd, maar als een kerncomponent van innovatie en impact.

De beleidsinvloed van living labs is ook onderzocht. De studie biedt inzicht in de huidige positionering van living labs binnen verschillende beleidsfasen en belicht de factoren die deze beleidsinvloed mogelijk maken. Hun invloed bleek het meest uitgesproken in de pre-beleidsfase, de implementatiefase en de post-beleidsfase, waar ze functioneren als grensinfrastructuren die het genereren van bewijs, het ontwerpen van interventies en adaptief bestuur faciliteren. Empirische analyse laat echter zien dat hun beleidsimpact afhankelijk blijft van faciliterende factoren zoals institutionele ondersteuning, betrokkenheid van belanghebbenden, focus op leren, hoogwaardig bewijs en integratie binnen bredere maatschappelijke behoeften en politieke agenda.

Samenvattend, het onderzoek (i) identificeert de kernkenmerken van living labs, (ii) maakt gebruik van leertheorieën om een analytisch living lab-leerkader te ontwikkelen, en (iii) onderzoekt hun effecten, voornamelijk in termen van hun leerresultaten en beleidsinvloeden. De focus van dit proefschrift ligt niet op de innovatie- uitkomsten van living labs per se, maar op het vergroten van het begrip van living labs en hun effecten. Als zodanig positioneert dit onderzoek living labs als een veelbelovende aanpak voor het aanpakken van complexe, klimaatadaptieve uitdagingen op het gebied van land- en waterbeheer. De inzichten benadrukken de noodzaak en het belang van het versterken van living labs als leergerichte, contextgevoelige en beleidsrelevante systemen die in staat zijn om klimaatadaptief land- en waterbeheer te bevorderen.

1

INTRODUCTION

In land and water management, a landscape is understood as a spatially diverse area where ecosystems, land uses, and water systems interact, forming an integrated functional unit that supports both natural processes and human activities (van Noordwijk et al., 2015). Under intensifying anthropogenic and climatic pressures, these landscapes require innovative and adaptive interventions to maintain their socio-economic viability, ecological integrity and cultural values (Haddeland et al., 2014). Conventional approaches, such as isolated soil conservation or drainage engineering, operate within sectoral and disciplinary silos and often fail to account for the interdependencies among land, water, vegetations and human systems (Falkenmark & Mikulski, 1994). Consequently, sustainable landscape transformation demand integrated strategies that simultaneously address diverse elements such as soil health, hydrological parameters, ecological connectivity and socio-economic functions (Falkenmark & Mikulski, 1994; Kirschke & Newig, 2021; Wehn & Montalvo, 2018).

Such transformation begins by planting seeds of knowledge through cross-disciplinary and sectoral collaboration among diverse relevant stakeholders including farmers, ecologists, hydrologists, planners, policymakers, and business actors (Mann & Schäfer, 2018; van Noordwijk et al., 2015). These seeds of knowledge germinate through iterative learning and adaptive management taking root in practice. For example, introducing mixed vegetation systems with diverse ground covers instead of monocultures can enhance soil health and water retention while supporting biodiversity corridors within production landscapes. The outputs or harvest of such a systemic approach is a multi-functional landscape that optimizes ecosystem services, water regulation, and soil fertility, while supporting human livelihoods (Weith et al., 2021). Ultimately, sustainable landscapes are not engineered in isolation but co-created through networks of knowledge and practice, where seeds of learning strengthen the roots of collaboration, with a prospect of yielding a harvest of ecologically-, socially-, and economically- viable and sustainable landscapes.

It is within this context that this dissertation titled 'Living Labs in Land and Water Management: Learning to Innovate and Innovating to Learn' explores the role of "living labs" as a novel approach to co-creation and innovation, adopting an overarching metaphor of plant cultivation.

1.1. INNOVATION IN LAND AND WATER MANAGEMENT

The growing interconnectedness between economies, environments, and policies, have made land and water systems increasingly complex (Newnham, 2005). This complexity is further intensified by climate extremes, such as severe floods and droughts, as well as by human activities that continuously reshape these systems (Haddeland et al., 2014). As a result, land and water challenges manifest in multiple forms, including soil degradation, water scarcity, declining water quality, recurrent flooding, pollution, inefficient infrastructure, fragmented governance, and competing stakeholder interests (Duda, 2017). Consequently, these challenges are recognized not only for their bio-geophysical and technical intricacies but also for the management and governance difficulties they pose (Kirschke & Newig, 2021).

Addressing such multifaceted challenges requires innovations that are both technically robust and responsive to economic, institutional, and societal dimensions (Moors, 2017). Indeed, shifting political, economic, demographic, and technological conditions demand novel approaches, making innovation central in navigating these emerging challenges (Magel, 2004). However, although innovation in land and water management has gained prominence, it faces persistent challenges arising from climate change, rapid technological advancement, and shifting societal values that exert pressure on existing systems (van der Brugge et al., 2005; Wehn & Montalvo, 2018). For innovation to be effective, it must be firmly anchored in the principle of sustainability, ensuring that the broader needs of both current communities and future generations are met (Newnham, 2005). This requires an integrated perspective and the active participation of diverse relevant stakeholders (Duda, 2017; Kirschke & Newig, 2021). Ultimately, co-creating with a broad range of stakeholders is critical to fostering innovative solutions capable of addressing today's land and water management challenges (George et al., 2016; Moors, 2017; Weith et al., 2021).

1.2. NATURE-BASED SOLUTIONS FOR LAND AND WATER MANAGEMENT

Nature-based solutions are increasingly applied to address the issues relating to land and water management by focusing on ecosystem-based innovations, while also supporting biodiversity and human well-being (Boelee et al., 2017; de Boer et al., 2019; Faivre et al., 2017). According to the definition of the European Union, NBS are inspired and supported by nature, are cost-effective, and help build resilience by simultaneously providing environmental, social, and economic benefits, thus resulting in more inclusive, resilient, and sustainable water- and landscapes (EU Directorate-General, 2022).

NBS designs exhibit more integration and address more diverse goals than traditional infrastructural or nature restoration projects (Slinger & Vreugdenhil, 2020). They can be implemented in a standalone fashion or in an integrated manner complementing other solutions, such as technological, engineering, and infrastructural solutions, to address societal challenges related to land and water management (Cohen-Shacham et al., 2016). In practice, the NBS can range from entirely ecosystem-based solutions, such as a mangrove forest, to solutions combined with traditional infrastructures, like a mangrove forest with a small dike behind it (Eggermont et al., 2015; Sowińska-Świerkosz & García, 2022). NBS include, for example, (i) natural infrastructure and ecosystem-based adaptation, such as forest landscape restoration; (ii) ecosystem-based disaster risk reduction, such as re-meandering of rivers and estuary or coastal defenses; and (iii) green and blue infrastructure (Cohen-Shacham et al., 2016; Sowińska-Świerkosz & García, 2022).

NBS have been applied in many land management efforts, such as improving the ecosystem functions of landscapes affected by agricultural practices and land degradation, while enhancing livelihood and other socio-economic functions at the same time (Miralles-Wilhelm, 2021), managing floodplains (Jakubínský et al., 2021), and enhancing suitable soil and landscape functions (Keesstra et al., 2018). Similarly, in terms of water management, NBS has been applied for flood and drought protection, for water purification, and in addressing the water-food-energy nexus, among others (Hartmann et al., 2019; Oral et al., 2020). Nature-based solutions underpin major EU policy priorities, particularly the European Green deal, the biodiversity strategy, and the climate adaptation strategy (Directorate-General for Communication, 2022). The EU's commitment to advancing nature-based solutions is reflected in several research and innovation programs, such as Horizon 2020, BiodivERsA ERS-Net, and the Horizon Europe (Directorate-General for Communication, 2022). Beyond the EU, several global initiatives promote NBS as integral to climate resilience and sustainable development. These include the United Nation Environment Program NBS initiatives (UNEP, 2025), the Climate Solutions Partnership by the World Resources Institute (WRI, 2025), and the Global Program on Nature-Based Solutions for Climate Resilience in collaboration with World Bank global practices (GPNBS, 2022). NBS implementation is more efficient when supported by innovative, participatory, and collaborative governance approaches (Lupp, Huang, et al., 2021), such as a "living lab" approach.

1.3. LIVING LABS IN THE FIELD OF LAND AND WATER MANAGEMENT

A living lab is an organized, rather than ad-hoc, approach to innovation, combining real-life experimentation with active user participation. In recent years, living labs have gained prominence as a transdisciplinary approach for addressing environmental challenges, such as land and water management by fostering innovative solutions (Peña-Torres & Reina-Rozo, 2022; Unger et al., 2022). Within these environments, close collaborations between different stakeholders and their networks accelerate the innovation process (Nyström et al., 2014) as participants contribute heterogeneous resources and knowledge to joint innovation activities (Leminen & Westerlund, 2012). Originally centered on ICT, living labs have since expanded across multiple disciplines, encompassing areas that address human behavior and social challenges (Mirijamdotter et al., 2006), such as urban planning, health, service innovation, public welfare services, and many more (Fuglsang et al., 2021). Moreover, newer living labs are often designed as hybrid organizational forms, strategically positioned at the interface of local administration, science, and society

(Scholl & Kemp, 2016). However, despite, or perhaps because of, their proliferation across multiple domains with diverse purposes, the conceptual understanding of the core elements constituting a living lab remains vague (von Wirth et al., 2020).

Living labs draw upon diverse conceptual foundations for their design. From innovation studies, the *Triple, Quadruple* and *Quintuple* helix framework, is influential in the design of living labs (Cai & Lattu, 2022; Carayannis et al., 2022). The *triple helix* model explains the interactions between academia, industry and government in fostering innovation and driving economic growth in a "knowledge-based economy". The *quadruple helix* introduces civil society as fourth dimension, making a shift towards "knowledge society" and "knowledge democracy," where innovation co-evolves with democratic participation. The *quintuple helix* incorporates nature, emphasizing that ecology, ecological sensitivity, and environmental protection should be regarded as drivers of knowledge production and innovation (Cai & Lattu, 2022; Carayannis & Campbell, 2010). Most living labs adopt one of these models, with quadruple helix predominating. Organizationally, arrangements are formed that bring public authorities, private actors, researchers, and citizens together, thereby enabling knowledge integration across institutional boundaries.

Another influential body of concepts centered on user-involvement and collaboration includes *user-participation, co-creation* and *co-production.* In public sector contexts like land and water management, the focus of this study, end-users are usually citizens or citizen groups (Voorberg et al., 2015). *User-participation* is a broad term including passive or active user-involvement, while *co-creation* refers to active participation of end-users throughout the process (Prahalad & Ramaswamy, 2004). *Co-production* focuses on collaboration between multiple producers, such as the diverse public sectors, citizens and communities, in producing a certain outcome (Miller & Wyborn, 2020; Nesti, 2017). In practice, living labs often use co-creation and co-production interchangeably. Many living labs also draw on or combine concepts such as *action research* (Procentese et al., 2025), *design thinking* (Anton et al., 2022) and *citizen science* (Veeckman & Temmerman, 2021), to list but a few. These diverse concepts were developed separately in different academic fields (Miller & Wyborn, 2020; Nesti, 2017), and may be applied differently in living labs based on their particular context and goals. This rich foundational base enables living labs to create a unique, open, user-centered, and collaborative environment where innovations can be co-created and tested in real-life contexts. Drawing on these concepts, this research broadly defines a living lab as, *"an organized, user-centric approach that drives innovation through co-creation among multiple stakeholders"*.

A living lab can be analyzed through its formation *(design)*, its operationalization *(activities)*, and its results *(effects)* (Thissen & Twaalfhoven, 2001). Its *design* is understood as the goals, resources, and context i.e., biophysical, socio-economic, and institutional components (Vreugdenhil et al., 2010); *activities* as means to foster co-creation and; *effects* as its output (innovation), outcomes, and impacts (McEvoy, 2019; Slinger & Kothuis, 2022; Thissen & Twaalfhoven, 2001). Living labs typically follow co-creative, participatory, and iterative innovation processes, employing a variety of methods, and activities. For example, brainstorming, vision development, peer-led learning, field experiments, workshops, seminars, supportive open (online and offline) communities, the use of serious games, and simulation modelling (Huang & Thomas, 2021), where the degree of stakeholder involvement differs across the activities. However, living lab literature tends to center on their contexts, designs, activities, and the methodologies applied, paying much less attention to their effects and the process through which these effects can be achieved (Voorberg et al., 2015).

1.4. CO-CREATION, INNOVATION AND LEARNING IN LIVING LABS

Living labs are widely seen as open innovation ecosystems based on a systematic user co-creation approach. Co-creation has emerged from the diverse fields such as service management, innovation management studies, marketing, and consumer research (Galvagno & Dalli, 2014). Within the living lab context, it generally refers to active participation of end-users throughout the innovation process (Hagy et al., 2017; Prahalad & Ramaswamy, 2004). It is a process of jointly defining and solving problems through collaborative interaction between different actors, including end-users, to foster innovation (Frow et al., 2015; Hagy et al., 2017) with each actor offering access to new resources through a process of resource integration (Prahalad & Ramaswamy, 2004). Thus, co-creation facilitates developing a much-needed cross-sectoral and socially inclusive understanding to address various problems, such as sustainable land and water management, leading to innovative solutions, as highlighted by Payne et al. (2008) and Slinger et al. (2022). However, co-creation is often seen as a 'virtue in itself' with little to no attention for how it drives innovation (Dekker et al., 2021; Voorberg et al., 2015).

Innovation can emerge as a valuable outcome of interactions, the sharing of knowledge, and the social encounters among the diverse actors (i.e., internal and external stakeholders, clients, civil society, etc.) engaged in co-creation (Frow et al., 2015). Similarly, the co-creation process may also be initiated as a learning strategy, where knowledge and information acquired during the learning process enable improved decision-making and drive the innovation process further (Edvardsson et al., 2012; Vargo et al., 2008). Co-creation involves the process of transdisciplinary learning and sharing of knowledge and experience that triggers transformation (Payne et al., 2008; Slinger et al., 2022). Payne et al. (2008) affirm that successful co-creation depends on learning and knowledge. When actors learn about each other, or learn from each other's knowledge and experiences, they learn to think collectively and surpass individual barriers—in essence, they co-create. In this sense, both co-creation and innovation are closely linked to learning within networks.

Despite the close interconnection between co-creation, innovation, and learning, and the fact that living labs mobilize existing knowledge, and generate new knowledge through their co-creation activities, the living lab literature rarely addresses the role of learning in these processes or its influence on the effects of living labs. Instead, living lab literature mostly focuses on direct and tangible innovations, overlooking the significant outcomes emerging from learning activities as well as the wider societal or policy influences associated with making changes

(Lux et al., 2019). Learning effects occur during a living lab's operation and extend beyond its boundaries as knowledge is transferred and applied in different contexts. Policy influence refers to the ways in which living labs inform, shape, or support decision-making processes, thereby contributing to climate-adaptive land and water governance Figure 1.1.

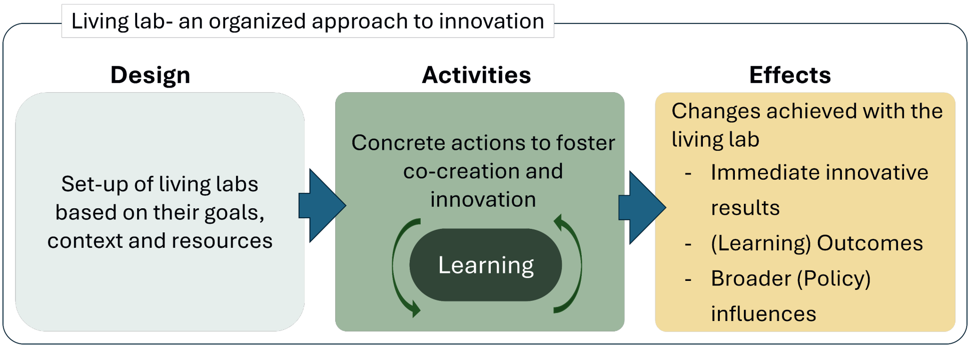


Figure 1.1.: Schematic representation of a living lab process, with a focus on learning within activities and the effects related to learning outcomes and broader policy influences (explored in this thesis)

1.5. THE KNOWLEDGE GAP AND RESEARCH QUESTIONS

Although living labs have been applied for more than two decades, their defining characteristics, operational models (learning within the activities), and resulting effects remain insufficiently understood (Paskaleva & Cooper, 2021). This limited understanding is largely attributable to a lack of systematic study of living labs and their effects, coupled with scarce evaluation and reporting on their performance (Paskaleva & Cooper, 2021; Puerari et al., 2018). This knowledge gap can be summarized in three key areas. First, as living labs are defined differently in different contexts and application domains, their defining characteristics remain ambiguous. Second, living labs lack a robust theoretical foundation, leaving the concept fragmented without deep theoretical roots. Third, insights regarding the learning outcomes and policy effects of living labs and ways to improve these effects are limited.

Exploring these knowledge gaps is critical not only for advancing academic understanding by clarifying concepts and generating transferable knowledge, but also for informing practice, enhancing accountability, and guiding the effective design, implementation, and upscaling of living labs. Thus, this research aims *to advance the understanding of living labs and their effects, particularly within climate-adaptive land and water management.*

The research objective is addressed through four central research questions:

RQ.1) What are the core characteristics of (nature-based) living labs?
Research Question 1 aims to identify the core characteristics of living labs, along with the unique characteristics of nature-based living labs. This exploratory question represents the initial stage of inquiry, addressing the need to establish a clear conceptual understanding of what constitutes a living lab, given the existing diversity within the field. We also examine the evolution of living labs over time to identify their core characteristics, explore variations within these characteristics, and determine additional scale-specific or domain-specific characteristics. In this regard, particular attention is given to nature-based living labs as they are increasingly applied within the context of land and water management, the scope of this research. The first Research Question provides a foundation for the subsequent stages of research and analysis.

RQ.2) How can learning be conceptualized and operationalized within the co-creative environment of living labs?
While learning during co-creative activities plays an important role in the development of innovative outcomes, it remains an underexplored domain. Systematically capturing this learning and building insights into ways of facilitating it within participatory and co-creative environments can significantly enhance both the innovative potential and the broader impacts of living labs. Accordingly, Research Question 2 seeks to examine diverse learning theories applicable to living labs and to develop an analytical framework for systematically capturing and evaluating learning outcomes within these settings. The answer to this question is grounded in a robust theoretical foundation of learning theories applicable to living lab characteristics.

RQ.3) How can living labs contribute to learning outcomes, particularly in the field of land and water management?
Research Question 3 builds upon the analytical learning framework developed in answer to Research Question 2, applying it empirically in designing and analyzing learning pathways within a living lab case-study to capture the broader learning outcomes. The implementation of the theoretically informed framework in a real-world case study enables a detailed analysis of how the learning process unfolds in practice. This empirical application not only validates the framework but also provides insights into its practical relevance and adaptability within co-creative environments.

RQ.4) How can living labs contribute to policy development, particularly in the field of land and water management?
Research Question 4 aims to investigate the effects of living labs in the wider policy landscape. This question seeks to map how living labs are positioned within policy processes and to identify the factors enabling living labs' policy influence. Policymaking is a non-linear, iterative, and highly contextual process that unfolds differently based on the policy field, socio-cultural context and

region. Therefore, this research question aims to deepen understanding of the policy contribution of living labs, specifically within Dutch land and water management.

1.6. RESEARCH APPROACH

This transdisciplinary and explorative research systematically analyses and synthesizes knowledge on living labs to advance knowledge on the defining characteristics of living labs and their effects beyond the immediate innovation. Most living lab studies are predominantly qualitative due to their case-specific and practice-oriented nature. The growing number of qualitative studies on living labs has also brought with it the need to synthesize this expanding literature base through quantitative analysis. Nevertheless, given the strong dependence of living labs on their contexts, in-depth case studies situated within specific environments remain a fruitful and rich approach in studying this phenomenon.

The research questions in section 1.5 are, therefore, investigated within the context of the CAtchment Strategies TOwards Resilience (CASTOR) project, funded under NWO-NWA 2019, with a primary focus on the Dutch sandy land- and waterscapes. For centuries, the Netherlands has actively shaped its land and water system to meet its needs, for example through polder drainage, and land reclamation (Stouthamer et al., 2020). In recent decades, under increasing climate and anthropogenic stresses, a shift is emerging within Dutch water and land governance, from controlling water to accommodating it and prioritizing adaptive management practices and ecological developments (Baptist et al., 2019). Examples include programmes employing nature-based solutions like Room for the River and the Sand Engine (Zandmotor) (Bontje & Slinger, 2017; Nijssen & Schouten, 2012). Given the growing need for innovation in Dutch land and water systems, living labs have emerged as an approach that functions both as a research and experimental infrastructure and as a governance mechanism (Schliwa & McCormick, 2016; Veeckman & Temmerman, 2021). Additionally, the 'sister' project of CASTOR namely, KLIMaat Adaptation in Praktijk (KLIMAP) (translated to: Climate Adaptation in Practice), that specifically focuses on sandy landscapes, serves as the starting point for the empirical research. KLIMAP is taken as a case study in chapters 4 and 5. Three other case studies investigated in this research (chapter 5) are Working with Water and Landscapes (WmW), Self-Supporting River System (SSRS), and the Schouwen-Duiveland Living Lab (SDLL). All the case studies partly or fully experimented with or implemented nature-based solutions, pursuing the overarching goal of stimulating innovation within Dutch land and water system through a collaborative living lab approach.

A mixed-methods research design that integrates both quantitative and qualitative methods (Creswell & Creswell, 2014) is employed in systematically analyzing and synthesizing knowledge on living labs at a meta level, both through theory development and case study observations. The metaphor of plant cultivation is employed in understanding and reporting the origins, learning, outcomes, and policy impacts of living labs. This metaphor is reflected in the titles of chapters 2 through 5 and aligns with the four major steps of the research (see Table 1.1), as,

1. Characterizing nature-based living labs from their seeds in the past
   This section addresses research question 1 and chapter 2. The first research question is addressed through the application of literature review methods, ranging from the snowballing approach outlined by Webster and Watson (2002) to the bibliometric analysis and systematic literature review techniques described by Linnenluecke et al. (2020). Relevant scholarly sources are identified using established academic databases, specifically Scopus and Web of Science (WoS). The snowballing method informed by bibliometric analysis outlines the living lab's evolution over time, and the systematic literature review identifies the core characteristics of living labs and nature-based living labs. The identified core characteristics form a basis for answering research question 2.

2. A living lab learning framework rooted in learning theories
   This section corresponds to research question 2 and chapter 3. The second research question is addressed by conducting a literature review on learning theories in relation to the core characteristics of living labs, using the method provided by Arksey and O'Malley (2005). Database engines such as Scopus and WoS are used to identify the relevant literature. The result of this literature review allows identification of learning theories that are relevant for living labs. Next, the selected theories are evaluated based on three major questions; "What type of knowledge is produced?", "How does learning occur in a specific learning theory?", and "Who is learning?" (Ropes & Thölke, 2010; Russell, 2006). This information is used to develop an analytical living lab learning framework with three interacting components: the what (learning types), the how (learning processes), and the who (learning levels) (Romijn et al., 2021; Ropes & Thölke, 2010).

3. Harvesting living labs outcomes through learning pathways
   This section, which addresses research question 3 and aligns with chapter 4, uses the methodology of case study research to harvest learning pathways, through application of the learning framework developed in chapter 3. As a tool applied in a real-life context, case study research (Yin, 2003) is selected as an appropriate method of empirical inquiry for investigating living lab projects. The living lab that serves as the case study is KLIMaat Adaptation in Praktijk (KLIMAP). The research adopts a mixed method, including (i) desk-based document analysis, (ii) participation in workshops and meetings, (iii) survey, and (iv) interviews. The survey was conducted and analyzed using Qualtrics software, and the interviews were coded using Atlas.ti data analysis software. The analysis captures co-creative activities with different learning types in KLIMAP and identifies their associated learning processes and learning levels to map the learning pathways.

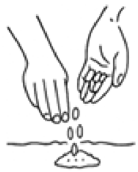
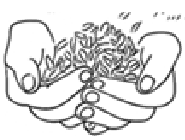
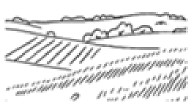
4. Influence of living labs in policy landscape
   This section addresses research question 4 and corresponds to chapter 5. First, the methodological approach draws on the insights into how the strategic activities undertaken in living labs align with different phases of policymaking.

Then, a literature review examines the policy-related contributions reported by existing living lab literature in terms of phases and activities. The result reveals the positioning of living labs across different policy phases. Finally, semi-structured interviews were conducted for four Dutch living labs to understand the factors that enabled their policy influence. A deductive qualitative analysis, as presented by Fife and Gossner (2024) was applied to categorize the responses to examine (i) the projects' designs, (ii) activities implemented, (iii) the goals achieved and (iv) how (or whether) the projects influenced policy. Questions concerned the project's context, design, outcomes, concrete policy contributions and enabling factors. The living labs that serve as cases for this chapter are KLIMaat Adaptatie in Praktijk (KLIMAP), Werken met Waterlandschapen (WmW), Self Supporting River System (SSRS), and Schouwen-Duiveland Living Lab (SDLL). These case studies extend beyond sandy landscapes to include some additional living labs representing a broader range of landscape types. This choice was made, as the policy perspective taken in this chapter requires a scope beyond that of sandy soil landscapes.

1.7. OUTLINE

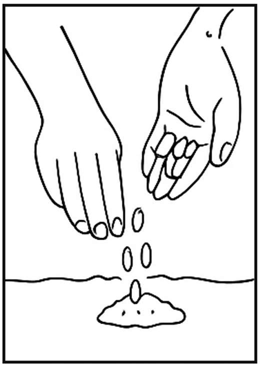
Following the introduction (chapter 1), the research questions are addressed in the subsequent chapters (chapters 2 to 5), with chapter 6 serving as a concluding chapter. Each chapter from 2 to 5 is a self-contained journal paper. Chapter 2 highlights how living labs have evolved over time, identifies the core characteristics that define living labs, and relates nature-based living labs to these characteristics while highlighting their uniqueness. The defining characteristics of living labs identified in chapter 2 form a basis for determining the learning theories applicable to living labs in chapter 3. Chapter 3 describes the development process and the living lab learning framework itself. The learning framework is applied to the KLIMAP case study to develop learning pathways in chapter 4. Chapter 5 explores the potential influence of living labs in the policy landscape and employs empirical investigation of additional case studies to identify the factors enabling these influences. Finally, chapter 6 synthesizes the outcomes of this dissertation by discussing the findings and presenting future research avenues.

Table 1.1.: Overview of research aims, methods, and their corresponding chapters

	Chapters	**Aims** (corresponding to RQ)	**Method**
	Chapter 2: Characterizing nature-based living labs from their *seeds* in the past	- Identify core characteristics of living labs and unique characteristics of nature-based living labs **(RQ 1)**	*Theoretical framework development:* Literature review
	Chapter 3: A living lab learning framework *rooted* in learning theories	- Explore learning theories relevant to living labs - Develop an analytical framework to capture (learning) outcomes **(RQ 2)**	*Theoretical framework development:* Literature review
	Chapter 4: *Harvesting* living labs outcomes through learning pathways	- Distinguish learning pathways in an empirical case using living lab learning framework **(RQ 3)**	*Empirical application:* Mixed methods: Process tracing, stakeholder interviews, survey
	Chapter 5: Influence of living labs in policy *landscape*	- Map how living labs are positioned within policy processes - Identify the factors enabling living labs' policy influence **(RQ 4)**	*Theoretical:* Literature review *Empirical application:* Four case studies analyzed using stakeholder interviews and document analysis

2

CHARACTERIZING NATURE-BASED LIVING LABS FROM THEIR SEEDS IN THE PAST



This chapter has originally been published as; Bhatta, A., Vreugdenhil, H., & Slinger, J. (2023). Characterizing nature-based living labs from their seeds in the past. Environmental Development, 100959.

ABSTRACT

Nature-based living labs combine the elements of nature-based solution design with a living lab context to address social and environmental resilience challenges. There is a need to deepen insights on the characteristics of the emergent phenomenon of nature-based living labs, with respect to their predecessors. Accordingly, the paper first develops an outline of how living labs evolved into nature-based living labs, informed by bibliometric analysis. Second, the unique characteristics of nature-based living labs are identified using a systematic literature review. Finally, the core characteristics of living labs are determined, and nature-based living labs are placed within this context. Initial living labs had a strong technological focus, which proliferated into diverse application domains and regions after the European Network of Living Labs was established and expanded. Urban living labs emerged as a significant multidisciplinary and geographically specific domain, while nature-based living labs are inherently sustainability-oriented and consider ecosystem processes, interactions, and natural materials. Next, the paper identifies nine characteristics of nature-based living labs, five of which are always present, namely: (i) real-life spatial context and multi-scale, (ii) innovation and learning, (iii) user-centric, (iv) multi-actor involvement and (v) sustainability-oriented multiple benefits. Then, the four core characteristics of living labs, the variation within these characteristics, and how these align with the characteristics of nature-based living labs are clarified. Finally, the need for research on living labs across application domains and regions is highlighted, so that the global applicability of these local, user-centric, innovative approaches can be established.

2.1. INTRODUCTION

The planet's land and water systems are undergoing continuous transformation by natural and human factors (Haddeland et al., 2014; Li et al., 2022). In recent years, the structure and functions of these systems are being altered further due to climate change (Haddeland et al., 2014; IPCC, 2022; van der Knaap et al., 2018). Likewise, the societal values attached to these systems that deeply engrain place-based cultures, traditions, and lifestyles are shifting under diverse future expectations (Bender, 2002). The complexities and uncertainties about the nature and extent of future changes pose challenges to the resilience of land and water systems (van der Knaap et al., 2018), both globally and locally. Therefore, landscape and waterscape management at the local and regional levels needs to integrate knowledge of the effects of climate change on these systems into relevant long-term strategic visions and to engage society in innovation processes for a resilient future. Such engagement of local communities to include their needs and perspectives on adaptation to climate change and their knowledge of local conditions can provide valuable inputs into policy and system planning (d'Hont & Slinger, 2022), and is potentially globally relevant for climate adaptation.

In the past, innovations that engage people were often characterized as linear processes driven and controlled by the developers (Mulvenna et al., 2011). However, open innovation via a network model that focuses on innovation activities through collaboration with external organizations has gained popularity (Busarovs, 2013; Mulvenna et al., 2011). A living lab is one such open and innovative approach that, in simple terms, involves a network of public-private-academic and other partners for real-life experimentation and innovation ("ENoLL Website", 2022). The living lab concept received strong attention from the European Union (EU) as a step towards renewing the European innovation system by creating multi-actor cooperation models for public-private-citizen collaboration. The focus on living labs in the research and innovation (R&I) agendas of the EU led to an increase in research projects relating to living labs, for example, the water-oriented living labs by Water Europe (Horizon 2020 Programme, 2017; WaterEurope & PNO, 2019). Research and innovation priorities at the EU level have a trickle-down effect on national research priorities (Quaglio et al., 2020). As a result, many national-level and regional-level organizations in Europe now include projects with living labs as an approach in their R&I agendas, resulting in many academics, researchers, policymakers, and practitioners active in the field of living labs. Even though existing research output is predominantly in Europe and USA, living labs are gaining increasing attention worldwide as they offer spaces where stakeholders can co-create innovative solutions to diverse problems at the interface between the environment and socio-economic development (Bouma et al., 2022; McLoughlin et al., 2018).

Nature-based solution (NBS) is one of the application domains in which living labs have emerged over the last couple of years (Lupp, Huang, et al., 2021; Lupp, Zingraff-Hamed, et al., 2021). Indeed, NBS has gained ground at the core of EU R&I policy for developing a long-term, sustainable, and resilient future (Schiavon et al., 2021). According to the IUCN definition, NBSs are "actions to protect, sustainably manage, and restore nature and modified ecosystems that address societal challenges effectively and adaptively, simultaneously benefiting people and nature". Nature-based designs exhibit more integration and address more diverse social goals than traditional infrastructural or nature restoration projects (Slinger & Vreugdenhil, 2020) and are exceedingly used in the field of land and water management. However, NBS implementation is more efficient when supported by innovative, participatory, and collaborative approaches such as living labs (Lupp, Huang, et al., 2021). Therefore, the establishment of living labs that pursue NBSs (nature-based living labs) appears to represent an organic way of channeling the shifts in land and water systems toward a climate-resilient future with societal collaboration.

NBS is often used as an umbrella term for a large spectrum of ecosystem-based approaches that address societal, environmental, and economic challenges (Cohen-Shacham et al., 2016; Sowińska-Świerkosz & García, 2022). NBS approaches include natural infrastructure and ecosystem-based adaptation, such as forest landscape restoration; ecosystem-based disaster risk reduction, such as reconfiguration of rivers, estuaries, or coastal defenses; or green and blue infrastructure, such as urban parks (Cohen-Shacham et al., 2016; Sowińska-Świerkosz & García, 2022) and green stormwater infrastructure (Zhou & Wu, 2023). Similarly, living labs, too, have become an umbrella term to label a diverse set of innovation milieus (Paskaleva & Cooper, 2021) that carry out a wide variety of approaches and activities (Leminen et al., 2017; Lupp, Zingraff-Hamed, et al., 2021). Emerging in such a multidisciplinary and diverse environment, the characteristics of nature-based living labs are not well-defined (Lupp, Zingraff-Hamed, et al., 2021). Researchers have attempted to characterize and classify living labs previously (Ballon & Schuurman, 2015; Schuurman, 2015; Schuurman, Mahr, et al., 2013; Steen & Van Bueren, 2017; Vale et al., 2018; Westerlund et al., 2018). However, Greve et al. (2021), McLoughlin et al. (2018), and McPhee et al. (2021) indicate the value of research on living labs across diverse domains. Accordingly, this paper seeks to deepen insight into the emergent phenomenon of nature-based living labs. Specifically, this paper aims to (1) provide an outline of the historical development of living labs leading to nature-based living labs, (2) identify unique characteristics of nature-based living labs, and (3) determine core characteristics of living labs and place nature-based within the context.

The paper is structured as follows. Following this brief introduction, the methods adopted in reviewing the literature are described, followed by a presentation and discussion of the findings of the review. This includes a description of an evolutionary outline of living labs from their early theoretical foundations to the current development of nature-based living labs. It is followed by an analysis of the characteristics of nature-based living labs and the identification of core characteristics common to all living labs in the dataset. Finally, the last section of the paper presents the conclusions, outlining the research limitations and the scope for further research.

2.2. METHODOLOGY

The paper employs different methods of literature review to realize each aim separately.

Aim 1: Considering the decades of diversity in living lab literature, the paper first aims to map a rough historical timeline of the development of living labs from their initial foundation to current-day nature-based living labs. Scholarly communication and document synthesis are exceedingly important in understanding the emergence, evolution, and proliferation of disciplines (Hérubel, 1999). As this part involved tracing the development path of living labs through time, a narrative of the emergence was developed by snowballing literature proposed by Webster and Watson (2002). First, a starting set of papers on the reviews of living lab literature were considered. Then, the history and state-of-the-art living labs were traced by consulting the articles cited by or referenced in this starting literature set. The reference lists of these articles were consulted in turn until a complete narrative providing an evidence trail of the origins and evolution of living labs was obtained (Jalali & Wohlin, 2012). In total, 34 papers (Dataset A1) were reviewed, spanning a time period from the early 2000 to the present. These papers were selected such that they helped in creating a chronological outline of living lab emergence branching to nature-based living labs. It should be noted that this was a subjective process, unlike the systematic literature review method.

Next, a bibliometric analysis was conducted to map the living lab landscape as proposed by Linnenluecke et al. (2020) and van der Have and Rubalcaba (2016) to support and validate the findings from the snowballing method. Author-keyword co-occurrence analysis was conducted for different timescales using VOSviewer software (van Eck & Waltman, 2010) for a minimum repetition of 10 and 5 words. Figure 2.1 informs the database of literature search, search keywords, data limitation and screening conditions, timelines developed, and total number of articles analyzed (Dataset A2) for each time period. The bibliometric analysis will highlight the keywords used at a certain point in time, thus quantitatively informing and validating the narrative formed.

Aim 2: The second aim of the paper, i.e., to identify unique characteristics of nature-based living labs, was achieved by conducting a systematic database literature review. A systematic literature review is adopted as the primary research strategy for this endeavor so as to collect a wide range of relevant peer-reviewed research evidence that covers the characteristics and current conceptualization of nature-based living labs as informed by Linnenluecke et al. (2020) and Munodawafa and Johl (2019). Both living labs and NBSs have emerged since the early 2000s (Cassin, 2021; Leminen et al., 2017). However, concepts similar to living labs and NBSs have existed in practice previously. Hence, to capture the concept of nature-based living labs in a comprehensive manner, keywords similar to living lab and NBS were used for the search conducted on Scopus and Web of Science (WoS) from May 2022 to July 2022. Basic information such as title, authors, publication year, name of the journal, and abstract of 141 unique papers were saved in a temporary MS Excel file. Next, the abstract of each article was read to ensure that these papers have living labs and NBSs as the main focus of the article, as shown in

Figure 2.1. Finally, the full text of the articles was consulted to obtain a small sample of articles (12) (Dataset B) that allow the characterization of nature-based living labs.

Aim 3: The third aim of the paper to determine the core characteristics of living labs and place nature-based living labs within the context, is achieved by aggregating datasets A1 and B.

AIM 1: DATA

Creating narratives of living lab emergence from initial living labs to present day nature-based living lab using snowballing method (Section 3.1)
Step 1.1: Starting set of 7 papers were taken (subjective)
Step 1.2: References of these 7 papers led to selection pool of 151 relevant papers, out of which 19 papers were selected after removing duplication and reading the abstracts. The papers were selected such that developing an evolutionary outline of living labs was supported.
Step 1.3: References of thus, selected 19 papers from step 2 led to additional papers. An additional 8 papers were selected for review after removing duplication and reading the abstracts.
Step 1.4: A total of 34 papers **(Dataset A1)** were selected.

Supported and validated by ↑

Bibliometric analysis of living lab literature from 2000-2023 to inform and validate the narrative developed Section 3.1)
Step 2.1: Scopus search keywords: "living lab" OR "living labs" OR "living-lab*" OR "Living laborator*" for four timelines; 2023-2019, 2018-2014, 2013-2009, 2008 and before.
Step 2.2: The document type limited to: article, conference paper, book, book chapter, review, conference review and editorial; Language limited to: English.
Step 2.3: Screening criteria: false positive results referring to living systems (soil, food, wildlife, animals) as living lab.
Step 2.4: A total considered (**Dataset A2)**

Timespan	2023-2019	2018-2014	2013-2009	2008-2000
No. of Papers	1341	968	491	73
Keyword Co-occurrence no.	10	10	5	5

AIM 2: DATA

Systematic literature review: (Section 3.2)
Step 1: Initial search keywords, *("Nature-based solutions" OR "building with nature" OR "designing with nature" OR "green-blue infrastructure" OR "green infrastructure" OR "ecosystem services") AND ("living labs" OR "living laboratory" OR "learning alliance" OR "open innovation" OR "co-creation")* in Title/Abstract/keyword section resulted in: SCOPUS → 127 papers
WOS → 94 papers
Step 2: Total → 141 unique papers *(After removing duplication)*
Step 3: The document type limited to: article, conference paper, book, book chapter, review; Language limited to: English.
Step 4: Screening criteria:
•*Include:* The paper explores NBS like concept in a living lab-like setting; AND supports **characterizing** living labs in the context of "working with nature".
•*Exclude*: The paper explores only NBS like concept or only living labs like concept, OR doesn't support characterizing nature-based living labs
38 papers were screened after reading abstracts.
Step 5: Finally, 12 papers **(Dataset B)** were selected after reading full article.

AIM 3: DATA

Aggregated literature: Dataset A1+ Dataset B (Section 3.3)
Out of 46 papers from Dataset A1 and B, 44 papers were selected for analyses after removal of duplication. These papers were selected to achieve aim (iii) i.e., to determine which are the core characteristics living labs and placing nature-based living labs within the context.

Figure 2.1.: Selection strategy adopted to achieve each aim in this study.

A qualitative meta-synthesis on dataset A1 and a statistical analysis of dataset A2 was conducted to identify the living lab evolution pattern. Similarly, a qualitative meta-synthesis of dataset B was conducted separately to identify unique characteristics of nature-based living labs.

For dataset A1, the timeline of the historical development of living labs to the current-day and their defining characteristics were developed to address Aim (1). The starting set of papers was selected that deal with the systematic literature review, history, and meta-analysis of living labs, allowing an initial understanding of living lab emergence, diversity regarding their application domain, innovation, and types of user involvement. In each publication, attributes such as the approximate timeline of living lab establishment, geographical location, context, and characteristics were investigated. These attributes were collected and analyzed to identify the historical timeline of living lab development and their respective characteristics. As this was a subjective method, a quantitative bibliometric analysis was conducted on dataset A2 to inform the narrative. To improve the readability of the visualization in VOSviewer, keywords such as “living lab”, “living-lab”, and “living labs” were all identified as “living lab”. Similarly, “nature-based solution”, “nature-based solutions”, “nbs”, and “ecosystem services” are identified as “nbs”, as proposed by Greve et al. (2021). Further, a bibliometric coupling of living lab literature based on countries was conducted to grasp the proliferation of living labs across different regions.

For dataset B, an analysis of the contents of the articles in light of Aim (2) produced a new understanding of the most important characteristics of nature-based living labs in relation to preceding living labs. In each publication, the living lab context, such as application domain, geographical area, scale, purpose, the involved actors, activities, innovation aims, the role of users, and focus on sustainability, were investigated. These attributes were then analyzed to identify the unique characteristics of nature-based living labs. A table highlighting the key findings from the selected literature is presented in the Appendix A (Supplementary material for chapter 2). Finally, the aggregation of datasets A1 and B was used to understand the core characteristics common to all living labs to address Aim (3).

2.3. Result and Discussion

This section is divided into three to shed light on each of the research Aims (1), (2), and (3), in turn. Section 2.3.1 seeks to establish the historical development of living labs, leading to the present-day nature-based living labs. A rough timeline of this development is depicted in Figure 2.2, which is examined and validated by quantitative bibliometric analysis in Figure 2.3. Section 2.3.2 identifies characteristics unique to nature-based living labs. Finally, section 2.3.3 discusses core characteristics common to living labs along with the range of variation within these characteristics and places nature-based living labs within the context.

2.3.1. History of living labs and the emergence of nature-based living labs

A. **American smart-home technology-driven living labs**

The early use of the notion of “Living Labs”, used interchangeably with the term “Living Laboratory”, took place in the late 1990s and is often credited to Professor William J. Mitchell and his research associates at the MediaLab and School of Architecture and City Planning, Massachusetts Institute of Technology

(Dutilleul et al., 2010; Eriksson et al., 2005). Even though Mitchell is noted as a pioneer of living labs, the term "Living Lab" occurred earlier in the scholarly work of other researchers (Følstad, 2008; Leminen et al., 2017). These living labs were usually used to indicate the "in-situ" nature of research (Ballon & Schuurman, 2015). Prior to Mitchell, Bajgier et al. used the term "living labs/laboratory" to describe students' experimentation to solve problems in Philadelphia (Lupp, Zingraff-Hamed, et al., 2021). Mitchell designed living labs to acquire more realistic and accurate information on the user's everyday life by observing their behavior in the usage of emerging home technologies for several days or weeks in the setting of a real home-like environment (Eriksson et al., 2005). The basic idea behind such living labs was to include users in the innovation (value-creation) of emerging technologies (Eriksson et al., 2005). These living labs were based on real-life experiments, were innovation-driven, and users were the subject of study so that the alignment of the products with user preferences could be improved.

The major difference between these living labs and the so-called "house of the future" or "homelabs" present at the time is that the focus of the living labs lay in making the innovation system user-centric while the latter stuck to being a showcase for technology (Eriksson et al., 2005; Markopoulos & Rauterberg, 2000). The technology showcase type of living lab is often referred to as the "American" notion of living labs (Schuurman, Baccarne, et al., 2013). In the 1990s, such as the Philips Homelab in the Netherlands and Fraunhofer InHaus in Germany already existed (Ballon & Schuurman, 2015). Nevertheless, Mitchell and his research team were considered influential in transferring living lab ideas from the US to the Nokia Corporation in Finland and, more widely in Europe, contributing to the rise of European living labs (Leminen et al., 2017).

B. **Early European ICT-driven living labs**

Living labs appeared as real-life testing and experimentation in mainstream research and innovation in private European ICT firms during the early 2000s (Følstad, 2008). One of the earliest European living labs is the "NokiaSpacelab real-life research environment", established in Finland in 2001 through the collaboration of the Nokia Corporation in Finland and Prof Mitchell's team (Leminen & Westerlund, 2019). From a commercial angle, many ICT businesses found it crucial to understand consumers in a real-life context. This led to tailoring the living lab concept to more general ICT-enabled applications, not only home technologies like the American living labs (Eriksson et al., 2005). During the same period, other living labs, such as "Vacation on Campus" at Eindhoven University, were designed as "a platform for collaborative research projects that would serve as a development and testing ground for novel technologies" with a vision of ubiquitous computing (Markopoulos & Rauterberg, 2000).

During the early 2000s, Europe wanted to prepare for the competitive global market through ICT innovation (Eriksson et al., 2005). Living labs were used to explore and innovate the quality of the user experience while using specific technologies, for example, mobile communication services. In this context, the living lab became an R&D method where ICT innovations were created and validated in real-life, user-centric, and open environments, which led to improved user-interface design, increased acceptance, and the co-design of innovations (Eriksson et al., 2005; Leminen & Westerlund, 2019). Living labs, therefore, represented a shift in innovation research, aiming to bridge the gap between technical parameters and human experience factors (De Moor et al., 2010). Designed for collaboration, these living labs focused on an open innovation environment since their initialization (Figure 2.3).

The European living labs formed a fundamental re-interpretation of the American notion of living labs: users were not studied in a home-like laboratory but rather in their everyday living conditions (Ballon & Schuurman, 2015). The idea of having users as co-creators arose from the notion that innovation is not created by systems but by humans and that the interaction of market, society, and technology is needed for highly accepted and economically feasible innovations (Eriksson et al., 2005). Thus, the initial living labs in the context of commercial ICT can be characterized as focused on real-life problems, user-centric, and driven by technological innovation based on a real-life environment.

C. **Establishment of the European Network of Living Labs (ENoLL)**

In Europe, the living labs movement gained momentum after the European Commission launched the Helsinki Manifesto in 2006 and established the European Network of Living Labs (ENoLL), promoting the European innovation system and stressing living labs as one key solution (Dutilleul et al., 2010; Schuurman et al., 2015). ENoLL aimed to connect scattered regional ICT living labs and support the formation of new living labs in an open platform by enabling knowledge exchange, networking, and shared innovation to foster standard methods and tools across Europe (Schuurman et al., 2015). Many European Commission reports, such as the i2010 policy statement, pointed out that Europe needed to catch up in its ICT investments (Eriksson et al., 2005). Thus, the EU policy framework for information society and media (i2010) supported living labs as strategic initiatives to strengthen innovation in ICT research (Ballon & Schuurman, 2015; Schuurman, Baccarne, et al., 2013).

Until the Helsinki Manifesto, the i2010 policy, and the formation of ENoLL, most living labs were scattered initiatives from private ICT firms and were not organized as a network. Commitment from public organizations is seen as essential to support systemic innovation in Europe, where public organizations are often responsible for the overall innovation system (Eriksson et al., 2005; Niitamo et al., 2006). Hence, the EU policy measure that supported and endorsed living labs for research and innovation provided momentum to living labs in Europe. The living labs were established as broad regional development programs to test, develop, and validate innovative products and services that fulfill future needs (Ballon et al., 2005). The endorsement of living labs and the formation of ENoLL to connect these living labs were strategic efforts to accelerate innovation systems for ICT in the EU. The initial 19 living labs established in different regions of Europe and connected through the open ENoLL platform explicitly supported the pillar “Strengthening innovation and investment in ICT research” within i2010.

D. **Diversification of living labs across application domains and geographical regions**
Soon after ENoLL’s establishment, living labs started branching into different contexts, application domains, and geographical regions. By 2010, ENoLL had become a legal entity and expanded its network outside of Europe to include members from non-European countries by establishing the Brazilian, Chinese, and African Networks of Living Labs, conducting workshops in Korea, and developing action plans in Australia and Singapore (“ENoLL Website”, 2022). Further, the World Bank and ENoLL developed a guidebook supporting living labs as a citizen-centric approach to innovation (Eskelinen et al., 2015) and recommending the living lab concept on a global scale. Eventually, living labs were established in many countries throughout the world, also independent of ENoLL’s network. A bibliometric analysis of living lab literature based on countries shows that besides European countries, living labs are evident in countries like the USA, Canada, Brazil, South Africa, Japan, China, South Korea, and Mexico, to name a few, see Appendix A.

The living lab approach, applied initially in technical and industrial contexts, has since expanded and developed through diverse contexts and settings (Eskelinen et al., 2015). ENoLL, while continuing to contribute to the EU digital agenda for local and regional development, branched out into several other contexts, such as innovation in public procurement, smart cities, and healthy aging (Angelini et al., 2016). Expansion of the application domains of living labs across disciplinary boundaries is a natural move where the innovation domain dealing with human and organizational issues are involved (Mirijamdotter et al., 2006), such as urban and rural planning, service innovation, health & well-being, and public services (Fuglsang et al., 2021). In addition to efforts from ENoLL, many European universities and educational institutions have adopted and adapted the living lab concept to link student creativity with the surrounding community for greater engagement and increased relevance of curricula (Eskelinen et al., 2015), leading to campus or university living labs. Similarly, many living labs (also outside ENoLL’s network) have been taken up by both urban and rural communities (later coined as urban and rural living labs) to strengthen local collaboration for development and promote “territorial innovation” at a regional scale; thus, making living lab a “policy tool” to enhance local and regional well-being through multi-faceted and citizen-driven innovation (Eskelinen et al., 2015; Leminen & Westerlund, 2012). Thereupon, in addition to technological solutions and ICT innovation (Mabrouki et al., 2010; Mutanga et al., 2011), rural living labs usually focus on environment disaster prevention (Lawo et al., 2008), business models (Schaffers et al., 2007), agri-food system (McPhee et al., 2021) and so on. Likewise, future internet and ICT-enabled "smart cities" (Schaffers et al., 2011) evolved into green or eco-cities (Anthopoulos & Fitsilis, 2014) and, ultimately, into urban living labs as socio-digital innovation environments in urban areas (Molinari, 2015). These living labs were initiated by a diverse set of stakeholders, including not only private businesses or academia but also public organizations and civil society (Leminen & Westerlund, 2012).

With increasing diversity in the application domains and disciplinary knowledge fields, living labs also showed variation in the degree of user involvement. The European living labs started to adopt different forms of user involvement by building upon the European tradition of user participation, e.g., the Scandinavian tradition of user contributions to design processes (Schuurman, Baccarne, et al., 2013). Hence, the role and intensity of user involvement in living labs have varied from user consultation and participation to user collaboration and co-creation (Arnkil et al., 2010). Similarly, living labs have expanded their focus from only technological innovation to various other (tangible or intangible) innovation ecosystems, such as social innovation (Franz, 2015), ecological, and environmental innovation (Metabolic, 2021). While some living labs were firmly rooted in their predecessors, a large group of living labs also focused on collaboration, co-creation, and knowledge exchange with users (Schuurman, 2015). With the new focus on user-centric and user-oriented innovation, the quadruple helix innovation model that includes private and public organizations, academia, and the users came into application (Arnkil et al., 2010). This network model of innovation meant that living labs were strategically positioned at the border of local or regional administration and society, adopting hybrid organizational forms (Scholl & Kemp, 2016) to allow opportunities for physical and digital activities (Bergvall-Kåreborn et al., 2015). A bibliometric analysis of keywords co-occurrence in the living labs literature over various timescales further proves the diversity of living labs across application domains and shows their transforming characteristics (Figure 2.3).

E. **Urban Living Labs**

Among many applications that have employed living lab approaches, such as health care, information technology, education, and energy efficiency, a significant development relates to their application in the "smart/ digital city" and "urban context". Living labs in the urban context, known as urban living labs, developed around 2011 and have become the most prevalent type of living lab in popularity and maturity (McLoughlin et al., 2018; Westerlund et al., 2018). As the scope of living labs expanded to different domains, it was inevitable that cities should receive attention, particularly as the concept of the digitalization of cities and the provision of internet access for citizens - "Digital Cities" - had already taken hold in Europe since the 1990s (Ballon & Schuurman, 2015). Furthermore, ENoLL contributed to forming a smart city portfolio, thus contributing to the foundation of the connected smart cities network (Aversano, 2016).

The initial aim was to achieve cities' development goals to become "smart or digitalized" cities (McLoughlin et al., 2018). However, the application range is not confined to digitalization (Voytenko et al., 2016). In Europe, over 70% of the population lives in urban areas such as cities, towns, and suburbs, and this is expected to increase to over 80% by mid-century (Directorate-General for Communication, 2022; Nabielek et al., 2016). With such a concentration of people from diverse backgrounds, cities are perceived as hubs of entrepreneurial and innovation activity. Urban living labs started to shape public spaces where city governments could engage citizens and steer co-design processes toward developing innovative services (Eskelinen et al., 2015; Mccormick & Hartmann, 2017). They were applied to tackle the challenges of sustainability and urban governance to achieve a broader learning experience, empower civil society, and exercise innovative forms based on actor participation (Chroneer et al., 2019; Voytenko et al., 2016). The urban living lab proliferated, moving from initial applications for smart/digital cities to applications for sustainable cities, with the emphasis shifting from users to civil society and from a narrower ICT or infrastructure focus to broader social, environmental, and governance aspects. Steen and Van Bueren (2017) present characteristics of urban living labs as innovation, co-creation, multi-participants, real-life context, and iteration. Furthermore, living labs do not have one single method but rather follow diverse methods such as observation, survey/interview, focus groups, public events, series of meetings, co-creation workshops, and so on (Huang & Thomas, 2021).

Established at the intersection of research, public innovation, and policy (with a networked or hybrid organizational form), urban living labs intend to design, demonstrate, and learn about urban innovations (Bulkeley et al., 2016). However, urban living labs deal with the urban context, which is not an application domain but a geographical locus. Various disciplinary fields co-exist within the urban landscape, leading to different understandings of what an urban living lab is supposed to achieve (Rizzo et al., 2021). In line with the EU research and innovation agenda, there has been a rise in the number of urban living labs that apply NBSs to develop resilience and increase the sustainability of urban communities (Sarabi et al., 2021), such as EU-funded Horizon-2020 projects (Chroneer et al., 2019). Urban living labs implementing NBSs are crucial in delivering environmental goals for cities with high population concentrations. However, their applications and the types of nature-based interventions they apply are relevant specifically to urban contexts, whereas there are living labs implementing NBSs in a wider geographical context.

F. **Nature-based living labs**

Although the population density of European cities has been increasing over the last 50 years, they occupy less than 20% of the total land area (Nabielek et al., 2016). Further, the cities are crowded with people and existing infrastructures, thus limiting possibilities for large-scale implementation of NBSs. Although effective, NBSs with their locus only in urban areas usually comprise small-scale interventions such as green roofs/ facades, underground water storage, free-standing living walls, or a single-line or group of trees. However, NBSs can cover a wide array of interventions at varying scales (buildings, neighborhoods, municipal regions) and loci (cities, coasts, river basins, rural areas, forest areas, agricultural areas, or mountainous areas) (DeLosRíos-White et al., 2020; Slinger et al., 2022). For example, the spatial scale of an NBS that aims to enhance biodiversity, strengthen climate adaptation, and address natural hazards is usually at a large landscape scale (Lupp, Huang, et al., 2021). Living labs implementing NBSs need to consider interactions at multiple scales across different geographical locations and need not be confined to the spatial scale or geographical context of the urban setting. Both living labs and NBSs must be tailor-made to be appropriate, as they are context-specific in both time and space (Cohen-Shacham et al., 2016). Thus, the living labs with a primary focus on innovation and implementation of NBS, termed nature-based living labs, are taken as a new application domain that exists across multiple scales and manifests at different loci (a few examples in Table 2.1).

The EU has positioned itself as a leader in "innovation with nature" (Zingraff-Hamed et al., 2020). While living labs form a part of the European Union (EU) research and innovation (R &I) agendas, NBSs support major EU policy priorities, particularly the European Green Deal, the biodiversity strategy, and the climate adaptation strategy (Directorate-General for Communication, 2022). The current policy goals of the EU regarding NBS are implemented under EU research and innovation projects such as Horizon 2020, the BiodivERsA ERS-Net, and the upcoming Horizon Europe (Directorate-General for Communication, 2022). At the same time, efforts to promote living labs as a citizen-centric innovation approach to development are being undertaken internationally ("ENoLL Website", 2022; Eskelinen et al., 2015).

Table 2.1.: Illustrative examples of Nature-based living labs.

Name	Aim	Stakeholders	Location
KLIMAP	Investigates the design of climate-adaptive ways for agriculture and nature using several NBS interventions. For example, investigation on the performance of perennial grain in terms of drought tolerance, biodiversity, and feed quality.	24 parties, including regional governments, knowledge institutions, & companies & farmers (in some field-experiments)	Sandy soil landscape in Netherlands; *Example from Middlebeers*
Living Lab Grens-maas	Delivers knowledge about NBS to support large-scale interventions for flood protection, thus contributing to water system resilience. As a part of the “Room for Rivers” project, the river system is allowed more space to hold water, at the same time increasing habitats for local wildlife “rewilding” and creating recreational space for inhabitants.	Climate café as a dynamic community of stakeholders; engagement with academic, public-private, and civil society	Netherlands, along the river Maas
Living labs 1.0 *by Circular Bioecon-omy Alliance*	Empowers nature and people by developing NBSs that enhance ecosystem services and foster sustainable livelihoods. For example, restoring forest cover using agroforestry to tackle the issues related to erratic rainfall, floods, and droughts while developing livelihoods through sustainable agriculture and land management practices.	Local communities, Local government, ARCOS foundation, Reforest’Action (knowledge company)	A global network of LLs for nature, people, & planet (Brazil, Italy, India, Columbia, etc.). *Example from Rwanda*
PHUSICOS Living lab *under the EU Horizon 2020 program*	Aimed at demonstrating the robustness of NBS in rural mountain landscapes. For example, reshaping the slope through wooden terrace techniques and establishing vegetation that stabilizes sediments to manage risks of erosion, rockfall, and landslides, at the same time decreasing the need for maintenance and adding aesthetic benefits.	The quadruple helix participation model (Zingraff-Hamed et al., 2020)	Norway, Italy, Spain, and France as demonstration sites.*Example from St. Elena, Spain*

A rough timeline summarizing the evolution of living labs through their initiation in America, their application in Europe, and their development towards the potentially globally relevant nature-based living labs is depicted in Figure 2.2. Section 2.3.2. explores nature-based living labs in detail, deriving insights on their unique characteristics.

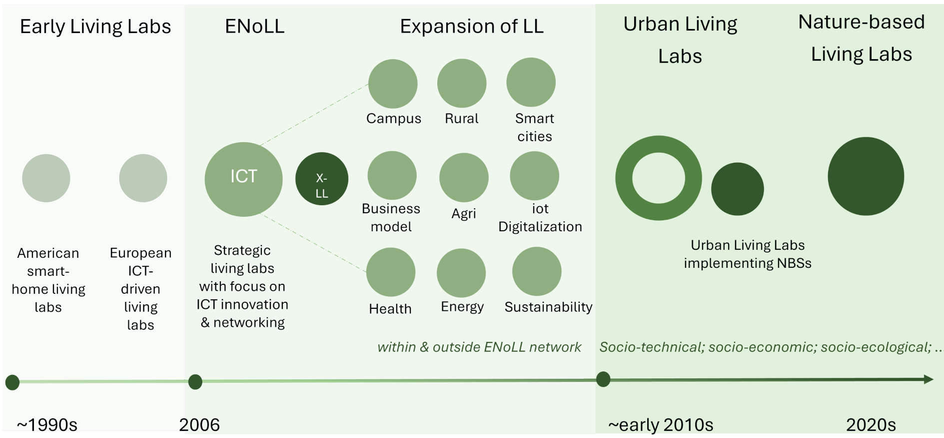


Figure 2.2.: A rough timeline showing the proliferation of living labs since their emergence leading to nature-based living labs; *where LL stands for "living labs"; X-LL stands for other domains of living lab application not itemized in the study; EnoLL stands for the "European Network of Living Labs".*

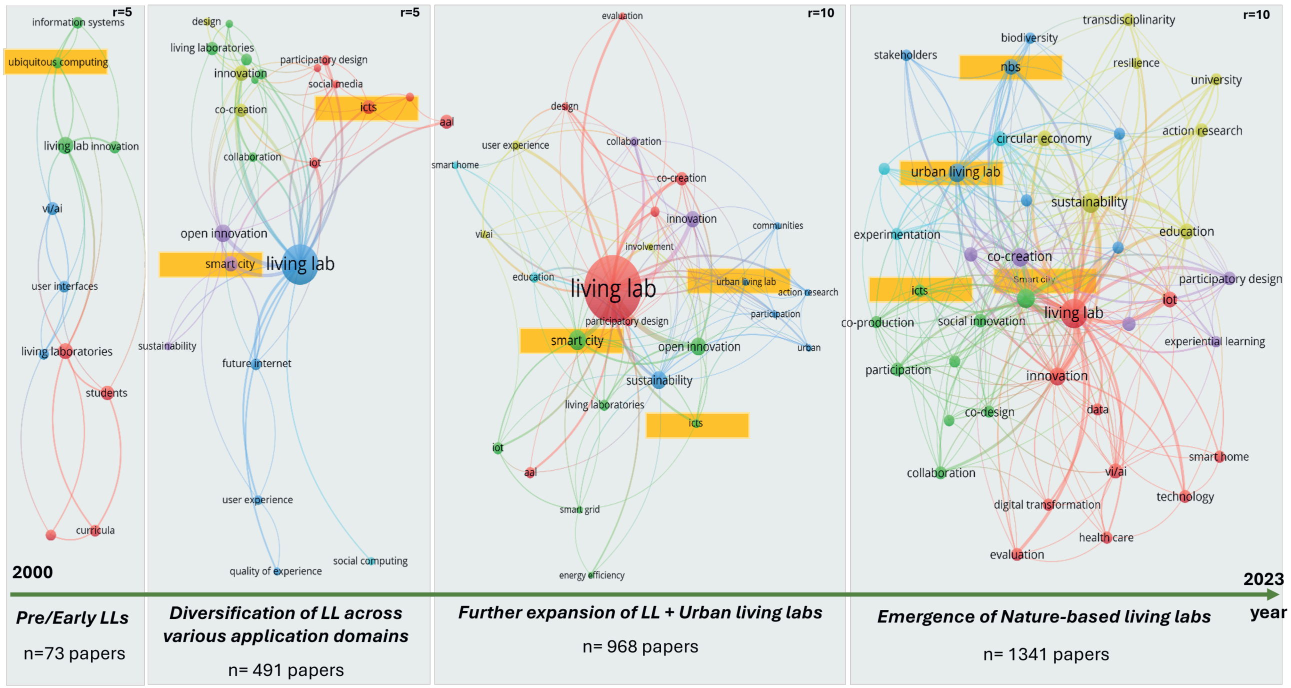


Figure 2.3.: Co-occurrence of keywords in the living lab literature, where highlighted keywords indicate the emergence of certain domains relevant to this paper. The left-most block shows ubiquitous computing evident in early living labs, followed by ict-driven, smart-city-related LL during ENOLL and its expansion. The Urban living labs appears in the second block from the right, and finally, LL applying NBS in the right-most block (at the top), *n = number of living lab literature analyzed; r = minimum number of keyword co-occurrence; Software: VOSviewer.*

2.3.2. Defining characteristics of nature-based living labs

Nature-based living labs combine concepts of NBSs and living labs. NBSs inherently require some elements of living labs, such as real-life context, multi-actor involvement, and multiple knowledge perspectives (Slinger & Vreugdenhil, 2020), which makes them compatible with the living lab concept. Other elements of NBS that are not inherently present in the living lab concept, such as the use of natural materials and ecosystem processes in the form of design artifacts and a long-term perspective, are additional characteristics of nature-based living labs (Slinger & Vreugdenhil, 2020). Thus, nature-based living labs enable co-creation in a transdisciplinary manner that contributes to various social and environmental challenges by pursuing innovation regarding nature-based artifacts, such as integrating water and landscapes using materials, forces, and interactions present in nature (Bouma et al., 2022; Slinger & Vreugdenhil, 2020). The transdisciplinarity of nature-based living labs lies in scientific cooperation between different disciplines and non-academic actors (Unger et al., 2022) and is supported by active collaboration between public and private sector organizations, academia, and civil society (McPhee et al., 2018). The results of transdisciplinary research enable mutual learning across the science-society interface (Jahn et al., 2012). Further, Bouma et al. (2022) suggest that a pragmatic approach focusing on collaboration between various relevant actors, such as land-users, nature conservation organizations, water boards, and researchers across different spatial scales, is needed to attain the goals articulated by the UN Sustainable Development Goals and the EU Green Deal.

The overview of living lab characteristics from various literature presented by Lupp, Zingraff-Hamed, et al. (2021), and Chroneer et al. (2019) provides starting points for characterizing nature-based living labs. Nine characteristics are found to distinguish nature-based living labs, the first five of which are always present in nature-based living labs, while the last four are sometimes evident (Table 2.2). A summary of the literature review from which these characteristics derive is presented in Table A.1 in the Appendix A.

A. **Real-life spatial context and multi-scale**
   Nature-based living labs occur in real-life settings. Real-life settings are the natural surroundings or environments where living beings and specific phenomena occur and operate, distinct from artificial laboratory settings (Leminen & Westerlund, 2012). Nature-based living labs are geographically embedded in the location where NBSs will be applied, or co-creation activities with stakeholders will take place (Chroneer et al., 2019). Nevertheless, many living lab co-creation activities, such as brainstorming, interactions, and visualizations, can occur digitally (Nunes et al., 2021) or use virtual reality. However, the real-life environment means that there are many interactions relevant to the geographic location that occur at a diversity of scales. This multi-scale aspect is a universal characteristic of a nature-based living lab, as captured in the literature review. The diversity in spatial scale can range from a building to neighborhoods, cities, or regions and is often interconnected across scales (Peña et al., 2020). Additionally, the varying scales can represent a diverse ecosystem and its interactions, such as forest areas, fields, river

basins, and coastal areas, thus underscoring the versatility and capacity of nature-based living labs to address various challenges.

B. **Innovation and learning**
One of the major characteristics of living labs is their practice-based innovation (Concilio, 2016). Innovation is the process of creating and using new ideas and concepts (O Riordan, 2013). Living labs provide a platform for exploration and experimentation that leads to the innovation of products, services, or solutions (Chroneer et al., 2019). Unlike most living labs, nature-based living labs do not focus on technological innovation through ICT and infrastructure products or services, making it particularly challenging to define their role in innovation (Chroneer et al., 2019; Rizzo et al., 2021). As nature-based living labs aim to derive solutions inspired by nature, their innovations may be viewed through a different lens - the lens of social-ecological innovation (Vreugdenhil et al., 2010). Additionally, many nature-based living labs are established for exploration, collaboration, and knowledge support, where learning is regarded as one of the outcomes. DeLosRíos-White et al. (2020) distinguish different innovation roles for the quadruple helix actors, namely: (i) civil society inclusion shifts innovation from the technical to the social sphere; (ii) academia contributes to knowledge innovation; (iii) public organizations create value for society through new strategies and policies, and finally, (iv) the private sector contributes to technological and organizational innovation.

C. **User-centric**
User-centric innovation approach means placing the users of the intended innovation at the heart of the collaboration network and prioritizing their feedback (Arnkil et al., 2010; Lupp, Huang, et al., 2021). The term “user-centric” is used as an umbrella term to include numerous ways and degrees of user involvement (see Figure 2.4) (Arnkil et al., 2010; Bergvall-Kåreborn et al., 2009). Most nature-based living labs support an intensive user collaboration such that they are engaged throughout the process to achieve a high degree of user involvement through co-creation (Lupp, Zingraff-Hamed, et al., 2021).

For nature-based living labs, users are usually stakeholders from the local civil society, the people most affected by the problem, and those who may benefit from the implemented solutions through value creation. However, living labs can also be designed with public authorities or private organizations as the users. Moreover, the degree of users’ inclusion and the intensity of participation differs for each living lab (Lupp, Zingraff-Hamed, et al., 2021). Despite being environmentally, socially, and economically relevant, the concept of NBS is less familiar to on-the-ground stakeholders (Lupp, Huang, et al., 2021). Hence, a nature-based living lab needs to accommodate differences in users’ perceptions and aim to form a mutual understanding of actions for successful execution.

The literature uses different “co-” terms to characterize living labs, such as co-design, co-develop, co-produce, co-implement, and co-manage, “co-” implying collaborative work. A particular focus on the term “co-creation”

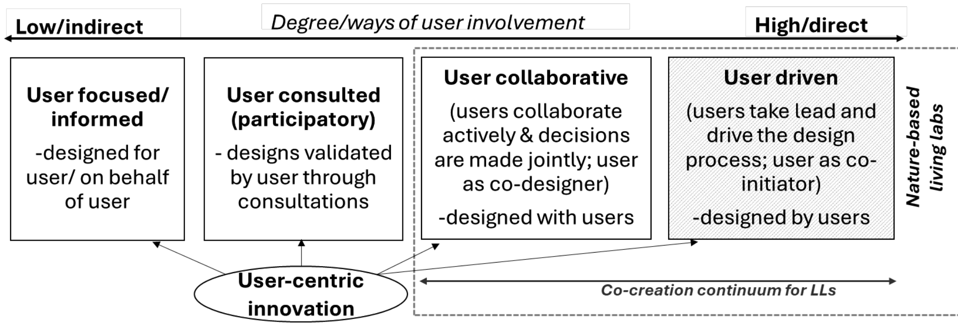


Figure 2.4.: Degree and ways of user involvement in innovation models; Adapted form (Arnkil et al., 2010; Bergvall-Kåreborn et al., 2009; Voorberg et al., 2015).

can be observed, which is a user-driven approach of working together with all stakeholders from the initial phase of the project throughout the process to achieve the project goal(s) (DeLosRíos-White et al., 2020). Co-creation ensures a paradigm shift from an organizational hierarchy towards integrated management and shared responsibility, with a more networked and institutionalized bottom-up way of working (Mahmoud & Morello, 2021). Co-creation has four key phases: co-initiation, co-design, co-implementation (Sillak et al., 2021), and a fourth phase of co-evaluation (Spagnoli et al., 2019). Some nature-based living labs involve a fifth key phase, namely, co-maintenance or co-management (DeLosRíos-White et al., 2020; Mahmoud & Morello, 2021). As a living system, NBS requires long-term maintenance and management planning among the stakeholders (Seddon et al., 2020). However, the degree of user-involvement may vary for different activity phases of living labs (Zingraff-Hamed et al., 2020).

D. **Multi-actor involvement**

Living Labs require the participation of multiple actors, mostly under the quadruple helix participation model (Calzada, 2019). Developed from the tri-helix innovation system framework that focuses on the interactions of public organization, academia, and industry, the quadruple helix adds a fourth dimension as “user” or “public” (Carayannis & Campbell, 2010), and the penta helix further adds a fifth dimension as “assemblers” that include social entrepreneurs, activists, brokers, NGOs, and so on (Calzada, 2019). The actors involved in living lab activities comprise civil society (the end users of the product, service, or solution), knowledge institutes (universities, research institutes), public actors (local/ regional government, public institutions), private actors (business firms and companies) and other relevant organizations. The public sector as an actor fulfills a regulatory role and potentially provides a long-term perspective, while the private sector often provides practical or business know-how and resources (Rizzo et al., 2021). Similarly, academia delivers expertise and scientific validation, while civil society is the target group and provides the behavioral definers (Rizzo et al., 2021). The actors interact and link with each other, developing collective dynamics that can lead to solutions.

Along with a focus on the multi-sectoral stakeholder network, some literature focuses on the multidisciplinary background of participants (Scholl & Kemp, 2016). This literature review reveals that nature-based living labs usually follow the quadruple helix participation model and create a cross-boundary arena or meeting space where diverse actors and organizations with multidisciplinary knowledge interact. However, Zingraff-Hamed et al. (2020) identify that “throughout the living lab process, stakeholder groups will have varying interests in different stages, providing expertise or being decisive or productive only in certain phases”. Furthermore, Alméstar et al. (2023) opted to embed the quintuple helix innovation model during their NBS co-creation process. Based on the quadruple helix model, the quintuple helix adds a fifth dimension as knowledge production in the context of the “natural environment” (Carayannis & Campbell, 2010). Apart from the human agents, the circulation of knowledge interaction to promote “sustainable development” and “social ecology” is a key element of the Quintuple helix model, which is likely a future trend in the field of nature-based living labs, given that they are inspired by nature.

E. **Sustainability-oriented multiple benefits**
Sustainability-oriented actions are not inherent to all living labs, but a deliberate addition (Sevaldson, 2018). However, nature-based living labs, by implementing nature-based artifacts, provide a wide range of ecosystem services that seek to move towards a sustainable future by overcoming particular environmental and social challenges. Thus, they offer a multiple-perspective approach by combining nature-centric with user-centric approach, making sustainability-oriented actions inherent to nature-based living labs. Some examples of environmental challenges that nature-based living labs tackle are climate change effects, heat stress, poor air and water quality, flash-floods and droughts, and biodiversity loss, whereas social challenges include reducing health and well-being, tackling unemployment and enhancing social cohesion, environmental justice, and citizen awareness (Arlati et al., 2021; Rizzo et al., 2021). The co-creation process in a nature-based living lab brings multi-stakeholders and their knowledge together to enhance and enable sustainable transition or transformation through NBSs. Actions aimed at sustainability are usually envisaged as providing multiple economic, social, and environmental benefits. Such multiple benefits characterize nature-based living labs and are highlighted in the literature where NBSs are implemented (Arlati et al., 2021; Clavin et al., 2021; Nunes et al., 2021; Rizzo et al., 2021), for example, parks and water bodies are designed to reduce regional heat stress, benefit the health and well-being of humans, and improve tourism. Further, the literature review indicates that additional, longer-term benefits include capacity building, practice-based knowledge production, positive behavioral changes, and possible business model development.

F. **Openness and equal power**
Openness in living labs is referred to as open development and innovation cooperation between living lab actors (Arnkil et al., 2010). Openness is considered one of the key characteristics of living labs (Eriksson et al., 2005; Leminen & Westerlund, 2012) but is not always clearly present in all nature-based living labs. However, some literature highlights challenges to openness arising from intellectual property rights as this is likely to arise as innovation progresses from experimentation to business models (Kviselius, 2009; Niitamo et al., 2006; Veeckman et al., 2013). However, most of the literature mentions little to nothing about openness. A complementary aspect of openness in living labs is the "non-hierarchical" or "equal" decision-making power between all participants and the possibility to join or discontinue association with living labs at any point. While some articles highlight the role of fixed key stakeholders (D. V. Gibson & Slovák, 2015), many provide empirical examples that indicate equal decision-making power in their living labs. However, they fail to explain the measures to ensure a non-hierarchical stance.

G. **Monitor and evaluate**
Monitoring activities and evaluation of living labs are not necessarily, nor thoroughly, carried out in all living labs. This is not a universal characteristic. Instead, only a few living labs extensively evaluate their process and progress. Nevertheless, monitoring and evaluating are essential to provide feedback on the effectiveness of nature-based living labs. To evaluate the initial outcomes of nature-based living labs, Lupp, Huang, et al. (2021) interviewed stakeholders regularly to assess their perspectives, learning processes, expectations of NBSs, and lessons learned from collaborative work. Arlati et al. (2021) and Mahmoud and Morello (2021) highlight the co-monitoring phase, which facilitates assessing the impacts of interventions on the environment of a city. Similarly, Mahmoud et al. (2021) developed a social monitoring framework to measure the social impact of NBS benefits.

H. **Business development**
Business development within living labs is not necessarily a universally applicable characteristic, but when present, it certainly can make living labs more successful. Developing a business model allows nature-based living labs to achieve longer-term financial success. However, only a few of the reviewed literature sources discuss the financial aspect of living labs. Mahmoud and Morello (2021) highlight the necessity for new business models to successfully implement NBSs and shed light on the financial challenges of securing long-term funds for managing and maintaining the interventions. Similarly, Lupp, Huang, et al. (2021) suggest that searching for economically attractive nature-based interventions is an approach to creating a business model within nature-based living labs.

I. **Iteration, spin-offs, and upscaling**
Although living labs effectively apply NBSs, it remains unclear how to diffuse

the knowledge built through the living labs experience beyond the locational boundary (Ribeiro & Lewis, 2021) so that it can be embedded in policy implementation (van Buuren et al., 2018). A growing number of researchers have applied the place-based dimension of innovation to emphasize the importance of local contexts for making innovation flourish (Rissola et al., 2017). Even though knowledge diffusion is at the core of many living labs, the innovations in nature-based living labs are recognized as highly context-dependent and site-specific, making replication of learning from them challenging (Sarabi et al., 2021). Most living labs lack mechanisms to iterate or translate into other socio-cultural, economic, and governance contexts, making "planning for iteration, spin-offs, and upscaling" a characteristic that cannot be found in all living labs. Nonetheless, some researchers address the challenges of iterating and upscaling living labs. In the literature review, projects such as UnaLab and Agrolab serve to highlight the diffusion of knowledge across different municipalities and cities (Chroneer et al., 2019; García-Llorente et al., 2019).

Table 2.2.: Characteristics always/sometimes present in nature-based living labs.

	Characteristics of Nature-based Living Labs	**Presence/ Occurrence**
Use of ecosystem processes, interactions, and natural materials	A. Real-life spatial context and multi-scale	Always present in nature-based living labs
	B. Innovation and learning outcomes	
	C. User-centric through co-creation	
	D. Multi-actor involvement from multi-sectors and multiple disciplines	
	E. Sustainability-oriented multiple benefits *through the design or implementation of NBS*	
	F. Openness and equal power	Not always reported/ evident in nature-based living labs
	G. Monitor and evaluate	Sometimes present in nature-based living labs
	H. Business development	
	I. Iteration, spin-offs, and upscaling	Not always reported/ evident in nature-based living labs

2.3.3. ROLE OF DIGITAL TECHNOLOGIES IN NATURE-BASED LIVING LABS

The current literature on nature-based living labs sheds little light on digital and technological innovations. However, there are indications that emerging technologies can be applied to fulfill specific needs within living labs, enhancing the potential for creativity (Lupp, Zingraff-Hamed, et al., 2021) and creating societal impact. Digital and technological innovation has been an important part of living labs from the outset. As living labs spread across domains, the innovations pursued have shifted from their primary technological focus to address social-ecological innovations. However, digital technologies, such as virtual reality or gaming simulations, can help stakeholders visualize or learn about implementing an NBS intervention and can assist in comparing against no-action situations (Piersaverio et al., 2019). For instance, the TUDelft Game lab undertakes many realistic simulations with a number of stakeholders using serious games (Lukosch et al., 2018). Similarly, WanderLab uses different visual scenarios that can be used to interact with stakeholders in a Living lab setting ("WanderLab", 2022).

Further, incorporating "smart" technologies into NBSs can assist in real-time monitoring of the solutions, increasing their reliability and making technological innovation possible in nature-based living labs (Piersaverio et al., 2019). However, Li and Nassauer (2021) caution that smart-NBSs may change familiar landscapes in novel ways, leading to the unintended loss of pleasant, everyday experiences. Thus, while digital technologies have the potential to enhance innovation and reliability in nature-based living labs, smart-NBSs will require a holistic understanding of social, ecological, and technical interactions. This understanding can be achieved through co-creation processes that engage professionals, researchers, and locals in sharing knowledge and perceptions (Li & Nassauer, 2021).

Table 2.3.: Summary of the characteristics of different types of living labs ordered based on their evolution, geographical location, application domain, and typology.

Characteristics	**American LL**	**European ICT-LL**	**ENoLL**	**Expansion of LL**	**ULL**	**Nature-based LL**
Simplified Evolution Timeline	Mid 1990s until early 2000s	Early 2000s	Mid to late 2000s	Late 2000s/early 2010s to date	Early 2010s/mid 2010s to date	Late 2010s/early 2020s to date
Geographical Location	Mostly USA	Europe	Europe	Predominantly in Europe, plus expansion globally	Predominantly Europe plus expansion globally	Predominantly Europe plus expansion globally
Major Application Domain (Objective)	Smart home technology	ICT, mobile application	ICT, smart cities, healthy aging, digitalization	ICT, not limited to, smart cities, health, energy, students' engagement & learning, agriculture, public procurement, etc.	Diverse application fields including but not limited to smart cities, smart grid, circular economy, urban food	Use of ecosystem processes, interactions, and natural materials; Application of NBSs to address social and environmental challenges, sustainability, and the interactions between human activities & nature
Living Labs (LL) Typology (Schuurman, Mahr, et al., 2013)	Original American living labs	Living labs as an extension to testbeds	Living labs to support context-related research & co-creation	Living labs to support context - related research and as policy instruments	Living labs for collaboration and knowledge creation	Living labs for collaboration and knowledge creation
Real-life Setting	Experiment in real-life setting, physical space	Experimentation in real-life setting, physical space	Experiment in real-life setting, physical and virtual space, Organizational arrangement	Explore, experiment and/or evaluation in real-life setting, organizational arrangement, physical/virtual space	Explore, experiment and/or evaluation in real-life setting, usually hybrid organizational forms	Explore, experiment and/or evaluation in real-life setting, geographical embeddedness, multi-scale, hybrid organizational/governance form
Innovation	Smart home technology (Digital innovation)	Information and Communications Technology (ICT)	Strategic ICT and innovation in technological sectors with a focus on local & regional innovation	Not limited to technology but applied to many other sectors with strong innovation possibilities with a focus on local and regional development	Various application domains applied to the urban context	Major focus on nature and society, collaborative governance, production of new types of products, services & processes
User-centric	User-focused, i.e., users are observed & used for feedback	User-involved or engaged through a participatory approach	Participation, Co-creation, or co-design	Participation, Co-creation, co-implementation	Participation, Co-initiation, co-creation, co-implementation	Participation, Co-initiation, co-creation, co-design, co-implementation, co-maintenance
Multi-actor Involvement	Academic, private, users (consumers)	Academic, private, users (consumers)	Public, academic, private, users	Public, academic, private, users, NGOs, interest groups	Public, academic, private, users, NGOs, interest groups, civil society; Transdisciplinary engagement	Public, academic, private, users, NGOs, interest groups, civil society; Transdisciplinary engagement
Sustainability	Not inherent	Not inherent	Not inherent	Not inherent, deliberate addition	Not inherent, deliberate addition	Inherent sustainability-oriented actions

2.3.4. CORE CHARACTERISTICS OF LIVING LABS AND NATURE-BASED LIVING LABS

The living lab concept has been seen as "an environment, a methodology, or an approach" (Bergvall-Kåreborn et al., 2009), an "innovation network" (Leminen & Westerlund, 2012), a "physical space, platform, or interaction space" (Zingraff-Hamed et al., 2020) and/or an "organization" (Svensson et al., 2010). Living labs follow a flexible and iterative rather than a rigid linear process (Unger et al., 2022). Each living lab uses a mix of diverse methods and approaches and is designed distinctively based on its context, prerequisite, available resources, and expected outcomes (Bhatta, Vreugdenhil, & Slinger, 2023). Synthesizing the material from the aggregation of datasets A1 and B (Figure 2.1), this section identifies core characteristics that unite the diverse living labs and places nature-based living labs within this context (summarized in Table 2.3).

In addition to the core common characteristics, Table 2.3 highlights an outline of living lab evolution across diverse geographical locations and distinguishes the purpose of the living lab. The factors, evolution, geographical location, application domain, and Schuurman, Mahr, et al. (2013) typology, therefore, appear in the first four rows of Table 2.3 and serve to specify the type of living lab being considered. Consequently, the remaining rows of Table 2.3 show four characteristics identified as being common to all living labs in the aggregated dataset:

A. Real-life setting: Even though the problem settings of living labs can vary in terms of their physical environment, the degree to which they are place-based and specific to a geographical location, and the scales at which they are implemented, all living labs address problems within their real-life contexts. The multiple scales relevant to the real-life problems addressed in nature-based living labs are a distinct characteristic of these living labs.

B. Pursuit of Innovation: The application domains and types of innovation may vary considerably across different living labs. Nevertheless, all living labs pursue innovation, be it social, economic, or technical, with some recent living labs explicitly pursuing learning as well.

C. Pursuit of Innovation: The application domains and types of innovation may vary considerably across different living labs. Nevertheless, all living labs pursue innovation, be it social, economic, or technical, with some recent living labs explicitly pursuing learning as well.

D. User-centric: All living labs are user-centric such that users are involved throughout the innovation process. However, the degree of user-centric can vary between different living labs or at different action points of the same living lab.

E. Multi-actor involvement: Living labs have diversified from a few actors to include many actors with diverse perspectives and interests. Recent time living labs conform to the quadruple-helix participation model.

If a living lab does not have all the four characteristics enumerated above, it has a different kind of approach and is not a living lab. A user-centric and multi-actor approach that pursues innovation but doesn't have a real-life problem setting could be a laboratory-controlled trial (Mohr et al., 2022), for example. Similarly, a real-life, user-centric approach to innovation that doesn't necessarily include multiple actors could be a demonstrative field experiment (Quak et al., 2016). A real-life, user-centric, multi-actor approach without the pursuit of innovation could include capacity-building projects. Finally, a real-life, multi-actor approach to innovation that is not user-centric could be a system-centric real-world laboratory (Huning et al., 2021). A living lab framework with its core characteristics and aspects of potential variation is presented in Figure 2.5. Similar to all other living labs, nature-based living labs have these four core characteristics to varying degrees but differ in that they are always sustainability-oriented with a focus on incorporating ecosystem processes, interactions, and natural materials.

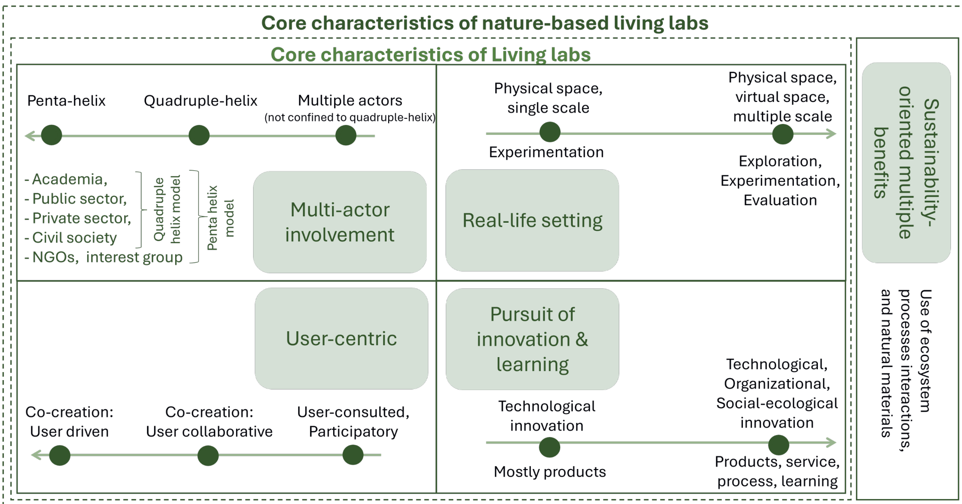


Figure 2.5.: Inner dotted line shows the core characteristics of living labs and the potential variation in the characteristics; outer dotted line shows the additional unique characteristic of nature-based living labs.

2.4. CONCLUSION

The first part of the literature study sheds light on how living labs have evolved historically, while the second part identifies the characteristics of nature-based living labs. Then, four core characteristics common to all living labs are identified, and the range of potential variation of these characteristics between living labs is indicated. Nature-based living labs are unique in their sustainability orientation and strong ecosystem focus.

The earliest living labs were scattered geographically, and their primary focus was to use users' experiences and feedback in innovating new ICT technologies. With the establishment of the ENoLL network, an open collaborative platform was established between various living labs within Europe. This facilitated the proliferation of living labs and their diffusion into several other domains, such as the health sector and service innovation. There was no strong theoretical foundation behind this proliferation, so living labs were used with varying intentions, such as for research, developing business (model), as a policy tool, co-creation and collaboration, citizen engagement, and learning activities. The expansion of living labs gave rise to urban living labs, which, unlike other application domains, are focused on a specific geographical context. Urban living labs made the living lab concept more familiar in diverse application areas, such as urban governance and urban climate adaptation and sustainability, thus acting as a forerunner of living labs pursuing NBSs.

Nature-based living labs specifically provide a collaborative space for stakeholders to develop innovative, environmentally driven interventions aimed at enhancing sustainability. The central defining characteristics of nature-based living labs are related to their real-life context, pursuit of innovation and learning, user-centric, the involvement of multiple actors and disciplines, and their focus on sustainability, the use of natural dynamics and natural materials, and the multiple benefits deriving from nature-based interventions. The real-life context of nature-based living labs means that they are associated with specific geographic locations in various scales, taking account of interactions at the neighborhood to the regional scale and at an individual wetland ecosystem to a river basin, for instance. In contrast to earlier living labs, nature-based living labs seem to have less scope for technological innovation as an objective per se, and a much broader and stronger pursuit of socio-economic and ecological innovation. Aiming for sustainability, they require multidisciplinary and multi-sectoral stakeholder participation, and seek to provide multiple economic, social, and environmental benefits. Further, they emphasize the user-centric approach through co-creation and co-maintenance at the interface between society, nature, and technology.

Living labs have proliferated since their initiation in the early 1990s and have broadened their application domains considerably. However, this research explored their development only through the lens of nature-based living labs, identifying characteristics common to all living labs, namely, real-life settings, pursuit of innovation, user-centric, and the involvement of multiple actors. The degree to which these characteristics vary between different living labs is considerable with nature-based living labs having place-based and multi-scale real-life settings, for instance. Similarly, nature-based living labs are inherently sustainability-oriented and give multiple benefits deriving from nature-based interventions that is not common to all living labs.

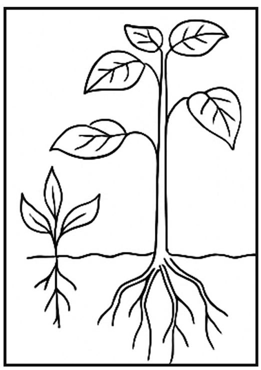
The literature review in this study was performed using Scopus and WoS in 2022. More recent relevant literature is, therefore, not included in this paper. Even though Scopus and WoS generally provide accurate and robust data along with significant extra search functionality, they have limitations in terms of their coverage outside academia (Mingers & Meyer, 2017) and are limited in their coverage of non-English language literature (van den Heuvel et al., 2021; van der Have & Rubalcaba, 2016).

Accordingly, this study may have overlooked the perspectives of policymakers and practitioners who were involved but not well-represented in peer-reviewed papers and of foreign scientists (Katzy et al., 2012). Many "lab concepts" similar to living labs, such as innovation labs and real-world laboratories, are not explored in the study. Further, this study doesn't explore the living lab concept that is being used under various regional names in different parts of the world, for example, in Columbia, where they are called Vivelab. The authors are particularly conscious of the Euro-centric view of living labs that is present in the literature and, therefore, call on researchers active in other areas of the world to supplement the understanding of living lab evolution and the characteristics of living labs presented in this research.

Living labs are currently in use as instruments for exploring local and regional responses to global challenges such as climate change and biodiversity loss. While this study has identified core characteristics common to all living labs and those specific to nature-based living labs, further research is required on how to enhance the efficacy of living labs. This study can provide a much-needed information synthesis for researchers and practitioners to help in formulating further research questions on the functioning, effectiveness, or design of nature-based living labs using database, case-study, or interview analyses. Cross-regional database analyses, expert interviews, and case studies of existing living labs, particularly nature-based living labs, could deepen insights and strengthen their contribution to climate adaptation. Moreover, cross-regional studies on the efficacy of different living lab platforms and the governance attributes that such networks can usefully adopt, would serve to strengthen living lab initiatives globally.

3

A LIVING LAB LEARNING FRAMEWORK ROOTED IN LEARNING THEORIES



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ABSTRACT

Complex issues like sustainable land and water management demand a transdisciplinary and collaborative approach, such as that of living labs, bridging between science, policy, and society. Living labs facilitate active collaboration among diverse actors from public and private sectors, research institutes, and civil society, creating an environment that fosters innovations to address environmental challenges. However, the impact of these labs is often assessed based only on their immediate results, overlooking the potential effects of learning during co-creation activities. Thus, this paper develops a framework that allows to capture learning in a living lab cocreative environment. In response to widespread calls for an epistemological basis for living labs, the study bases the framework on relevant learning theories. First, the literature dealing with learning theories relevant to the characteristics of living labs is reviewed. The relevant theories are identified as: behaviorism, cognitivism, constructivism, experimental, situated, social, organizational, transformative, and connectivism. Next, the insights on learning theories are used in developing a Living Lab Learning Framework with three interacting components: A. Learning types (what), B. Learning process (how), and C. Learning levels (who), contributing to learning outcomes. The framework distinguishes content, capacity, and network as learning types; intentional or incidental as learning processes; and individual, team, and organization as learning levels. Finally, the potential application of the framework during the initiation, implementation, and evaluation project phases of living labs is highlighted. The framework is envisaged to extend the impacts of living labs beyond immediate results by providing a systematic method for assessing learning and its outcomes and generating insights regarding future improvements in the configuration of living lab learning environments.

3.1. INTRODUCTION

Complex societal challenges, such as establishing sustainable land and water management, demand an integrated approach and engagement of relevant stakeholders (Bhatta, Le, et al., 2023; Eberle et al., 2021). Spanning across technical, organizational, social, and political dimensions, these challenges are inherently dynamic and multifaceted (Bhatta et al., 2024; Mitiku et al., 2006). The increasing risk of climate extremes, combined with changing social dynamics and usage patterns, further amplify these complexities (Bhatta et al., 2024). The prevailing uni-disciplinary and sectoral approaches are thus, ineffective in addressing these issues, requiring adaptive, iterative, collaborative and transdisciplinary learning approaches that connect across the boundaries of science, policy, and society (Biberhofer & Rammel, 2017; Kørnøv et al., 2022).

An example of an increasingly applied collaborative approach that addresses these complex issues is the "living lab" (Ebbesson et al., 2024; Hagy et al., 2017; Rădulescu et al., 2022). The term "living lab" is often used loosely and sometimes even strategically across diverse projects (Leminen & Westerlund, 2014), similar to the use of term "pilot project" (Vreugdenhil et al., 2010). Conversely, many initiatives that exhibit the characteristics of living labs are not labelled as such (Lupp, Zingraff-Hamed, et al., 2021). Key aspects of living labs include: (1) a focus on a real-life environment (Eriksson et al., 2005), (2) an iterative, experimental design with innovation as intended outcome (Pallot & Pawar, 2012; Westerlund & Leminen, 2011), (3) a transdisciplinary and multistakeholder approach to knowledge creation (Compagnucci et al., 2021), and (4) a long-term orientation toward societal transformation (Backhaus et al., 2023).

Since their initial establishment, living labs have been applied in addressing sustainability issues across diverse domains, such as smart cities, urban and rural planning, land and water management, provision of ecosystem services, and public governance (Bhatta et al., 2024; Hilbers et al., 2024). Recent research positions living labs as a means of addressing complex societal and environmental challenges; for instance, van den Berg et al. (2023) point out the role of living labs in accelerating sustainable land management on a community level; Marselis et al. (2024) highlight living labs as a learning platform for sustainable agricultural (land) transition; Alamanos et al. (2022) utilize living labs for integrated water resource management, and Ruiz-Ocampo et al. (n.d.) highlight the role of water-oriented living labs in validating circular water solutions. Tailored to the "context of application", living labs embrace adaptability and iteration in real-world contexts (Bhatta et al., 2024; Hermans et al., 2013). They facilitate active collaboration and co-creation among diverse academic and non-academic actors from public and private sectors, research institutes, and civil society, enabling transdisciplinarity (Unger et al., 2022). By engaging multiple disciplines and sectors, access is granted to heterogeneous resources and knowledge, cultivating an environment conducive to innovation for sustainable development (Edwards-Schachter et al., 2012; Leminen & Westerlund, 2012).

Even though innovation is traditionally viewed from an individualistic perspective, innovation originates from the co-creative environment where diverse ideas can gestate and interact over time (Fagerberg, 2006; Howells, 2002). Thus, knowledge exchange, mutual learning, and interactions during co-creation lead to innovative outcomes and impacts (De Silva et al., 2023; Sánchez & Mitchell, 2017). The success of cocreation in fostering innovation depends on two core competencies: (i) integration of different types of relevant knowledge, skills, and resources; and (ii) the promotion of mutual learning among the actors (Daniels & Walker, 1996; Kohlgrüber et al., 2021). Co-creation does not require consensus; instead, it requires mutual empowerment to achieve a bigger goal in the larger picture (Rill & Hämäläinen, 2018). Therefore, co-creation leads to desired impacts only if either formalized or ad-hoc learning occurs within the given network of actors (Kørnøv et al., 2022; van den Berg et al., 2023). Here, learning is viewed as a continual and integrated knowledge and values creation rather than an outcome-focused process (Sánchez & Mitchell, 2017).

However, many scientific works that indicate co-creation as one of the crucial factors in innovation often overlook the role of learning (Cinar et al., 2024; Stockstrom et al., 2016). Similarly, transdisciplinary research tends to focus on immediate output and often ignores the potential impacts of activities and learning processes (Lux et al., 2019). In living labs, attention primarily centers on the contexts, methodologies, and intended outcomes, with little consideration for what is being learned, who is learning, and the processes supporting the desired innovative outcomes. Despite this oversight, living labs harbor multiple sources of knowledge, mobilize existing knowledge, and generate new knowledge (Lehmann et al., 2015). Insights into ways to facilitate learning within participatory and co-creative environments, therefore, can significantly enhance their innovation capacity and potentially influence decision-making (Andrade et al., 2022; Sinclair et al., 2008). Furthermore, existing research stresses the need to explore understudied aspects of living labs with appropriate theoretical foundations (Puerari et al., 2018; Ståhlbröst, 2008). Accordingly, this paper explores diverse learning theories relevant to living labs to provide an epistemological basis for living lab learning. Learning theories provide insights into how individuals, groups, and systems acquire knowledge and how this learning results in collaboration, adaptation, and innovation (Harasim, 2017). The insights garnered on learning theories are then used to develop an analytical framework to capture learning outcomes and guide the design of the participatory, iterative, and systemic processes necessary to address complex societal challenges effectively (Tasir & Hao, 2024).

The paper is structured as follows. After this introduction, a theoretical background on the epistemological underpinning of learning theories is provided, followed by the methodology section. Next, relevant learning theories applicable to living labs are explored in relation to their core characteristics, culminating in the development of an analytical living lab learning framework. Finally, the last section of the paper presents the conclusions, outlining the research limitations and the scope for further research.

3.2. EPISTEMOLOGICAL ASSUMPTIONS OF LEARNING THEORIES

Learning theories help us understand how learning occurs and how knowledge is acquired (Harasim, 2017). The perspectives adopted by learning theories are influenced by their epistemological positions (Ataro, 2020; Kelly et al., 2012). Epistemology deals with the nature of knowledge and the way of acquiring and communicating knowledge (Ataro, 2020), thus, is essential for making judgments about current learning processes and for improving and redefining future learning approaches (Harasim, 2017; Stoten, 2024). Two main schools of thought dominate discussions on the nature of knowledge: Objectivist and Constructivist (Ataro, 2020; Cronjé, 2006; Harasim, 2017). Objectivism epistemology asserts that knowledge exists independently of the knower, while constructivism argues that reality is internally shaped by individual's subjective understanding and interpretation (Figure 3.1) (Cronjé, 2006).

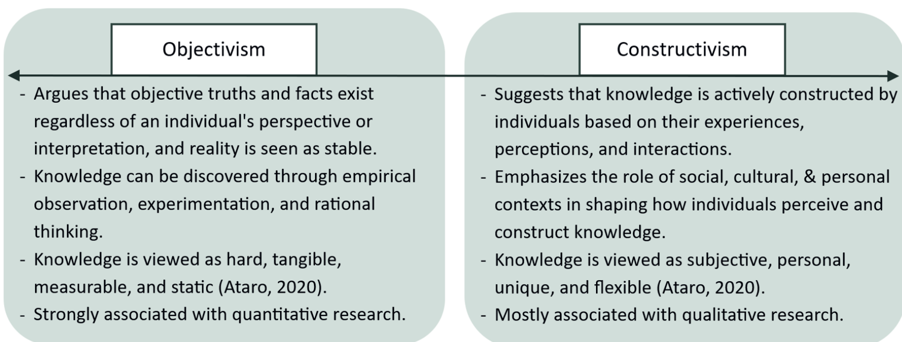

Figure 3.1.: Objectivism and constructivism continuum.

The broader landscape of epistemic theorization is enriched by several views on how knowledge is acquired, validated, and applied. Some key epistemologies related to objectivism and constructivism to various degrees include critical realism, pragmatism, social constructivism, and post-modernism (Barfi et al., 2021; Cruz et al., 2021).

The perspective adopted in a co-creative environment influences its embedded epistemological assumptions, guiding its methods and designs (Bhatta et al., 2025b). Moreover, transdisciplinary and collaborative research, such as living labs, demonstrates that epistemological viewpoints are fluid and can change throughout the task, project, or research (Cruz et al., 2021). Traditionally, learning theories aimed to understand human behavior, with three major types: behaviorist, cognitivist, and constructivist, emerging in the twentieth century. While these theories are well-established, they primarily explain relatively simple forms of learning (Steffens, 2015). Consequently, the twenty-first century has seen the development of new learning types driven by complexities, collaborative approaches, and digital advancements.

In the case of living labs, learning doesn't fall within the traditional teacher-student settings. Instead, participants are adults with diverse backgrounds, experiences, and memories who actively share knowledge, exchange insights, and collectively contribute to the learning experience. This approach shifts the focus from pedagogy, where teachers control what and how learning occurs, to andragogy, which emphasizes self-directed, interactive adult learning, or even heutagogy, characterized by self-determined, proactive, and technology-assisted learning (Glassner et al., 2020; Holmes & Preston, 2020). Adults are inclined to learn things relevant to their own life situations (Illeris, 2003), thus collaborative and co-creative learning should be viewed from the learner's perspective. The epistemology in such practices is multi- layered and evolving (Heath, 2014). However, by adopting an appropriate outlook, different learning theories can be combined to compensate for the limitations of individual theories, as demonstrated by V. F. Hendricks (2006), Carman (2002), Dangwal (2017), and Sabri (2017). Indeed, learning is too complex to be the sole province of any one theoretical perspective, research, or method (Bell, 2004). Instead of seeking a singular approach, we, therefore, explore diverse learning theories that align with the multifaceted nature of living labs.

3.3. RESEARCH DESIGN

The first part of the research aims to explore and identify learning theories relevant to living labs. A Scopus and Web of Science (WOS) databases search using keywords "learning theor*" AND "living lab*" yielded only four papers (Blezer et al., 2024; Knickel et al., 2023; O'Brien et al., 2021; van der Horst & Staddon, 2018). However, each term searched individually yielded 25,227 and 3708 papers respectively. To focus our search, we therefore chose to investigate learning theories in relation to the core characteristics of living labs rather than the term itself. Bhatta et al. (2024), define the core characteristics as: based in "real-life setting", pursuing innovation", "user-centered" ("co-creative"), and involvement of "multi-stakeholders" ("quadruplehelix"), and identify two additional key aspects of living labs, namely a focus on "sustainability" and cognizant of "digitalization". Overall, the method provided by Arksey and O'Malley (2005) was followed in this review process, i.e., identifying relevant papers via different sources, selecting papers, organizing the data (e.g. in MS Excel), and summarizing the result analysis (Figure 3.3). The literature search was conducted on Scopus and WOS using the keywords "learning theor*" AND [("real-life context" OR "real-life setting"), ("innovation" AND Doc Type "review"), ("user-centered" OR "user-centric"), ("co-creation" OR "co-creative"), ("multi* stakeholders" OR "quadruple helix"), ("Digital age" AND "digitalization"), ("sustainability" OR "sustainable")] in the title, abstract, and keywords. For the term "innovation", only review papers were selected as a non-limited search returned 865 papers in Scopus alone. The keywords used yielded 287 papers (Table 3.1). A complete list, including titles and the learning theories utilized in these papers, is available in the Appendix B (Supplementary material for chapter 3), table A-C; chart A).

Table 3.1.: Keywords used for search in Scopus + WOS.

					No. of Papers
"Learning Theor*"	AND	"Real-life setting"	OR	"Real-life context"	13
		"innovation"	OR	Doc type "review"	66
		"User-centered"	AND	"User-centric"	33
		"Co-creation"	OR	"Co-creative"	33
		"Multi* stakeholders"	OR	"quadruple helix"	23
		"Digitalization"	OR	"Digital age"	79
		"sustainability"	OR	"sustainable"	40
				Total papers:	287

After removing duplicates, the remaining 276 papers were examined to determine if they applied or were based on a certain learning theory, second circle in Figure 3.2. By searching for living lab core characteristics, we were able to obtain articles in which co-creation, user-centric, iterative and systemic aspects were evident, yet the authors didn't use the term living labs.

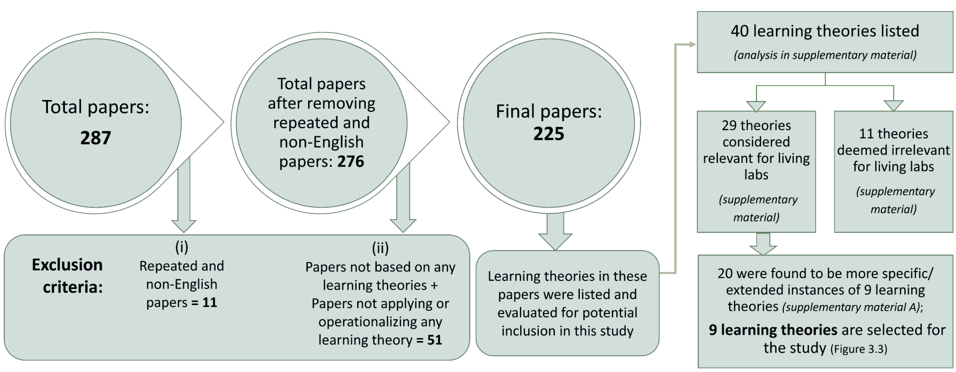

Figure 3.2.: Strategy adopted to select the papers and learning theories applicable to this study.

The analytical process followed in extracting the learning theories comprises the following steps: First, the papers were screened using their abstracts to identify the learning theories that the authors of these papers claimed to have applied or operationalized. When the abstract didn't clearly indicate which learning theory was utilized, the full paper was examined. The 51 eliminated papers referred to learning theories, but didn't actually apply them. The learning theories in the remaining 225 papers were then listed explicitly. For example, in the Appendix B, Table C, paper C-8, Hosseini and Okkonen (2022) state that they employed transformative and adult learning theory in a user-centric context; thus "transformative" and "adult" learning theories are listed. Similarly, for paper E-8 by Zada et al. (2023) "social" learning theory is listed as the paper states that it is grounded in social learning theory in a context that involves multiple stakeholders. In this manner, 40 learning theories were listed (Appendix B, Table D). The learning theories differed in their occurrence frequency and level of abstraction. The more frequently occurring theories (ten or more mentions) were well-established and widely used, whereas the less frequent ones (five or fewer mentions) were relatively niche and appeared in specific instances. All identified learning theories were analyzed for potential inclusion in this study. After analyses, nine theories were deemed to be at a consistent level of abstraction, and twenty were found to be more specific or extended instances thereof, while the remaining eleven were considered to be of little or no relevance to this study (argumentation can be found in Appendix B; Table E). The nine theories are presented in Figure 3.3 in the result section. The full analysis was carried out by the first author, with the other authors independently reviewing the findings.

Next, we evaluated the selected theories based on three major questions; “What type of knowledge is produced?”, “How does learning occur in a specific learning theory?”, and “Who is learning?” (Ropes & Thölke, 2010; Russell, 2006). This information was used to develop an analytical living lab learning framework with three interacting components: the what (learning types), the how (learning processes), and the who (learning levels) (Romijn et al., 2021; Ropes & Thölke, 2010). Learning types were distinguished as instrumental (substantive) knowledge, practical capacity learning, communicative knowledge, network knowledge, and critical reflection based on the work of Cranton (2001), Galway et al. (2016), and Vreugdenhil et al. (2010). Similarly, for each learning theory, the central learning process was identified. Finally, we built our understanding of learning levels based on Huber (1991), Ropes and Thölke (2010), and Sessa and London (2015) as individual, group, and organizational levels. All these inputs were used to realize the living lab learning framework.

3.4. RESULTS AND DISCUSSION

Nine learning theories were found to be the most relevant to living lab environments, namely behaviorism, cognitivism, constructivism, experiential, situated, social, organizational, transformative, and connectivism learning theories, as shown in Figure 3.3.

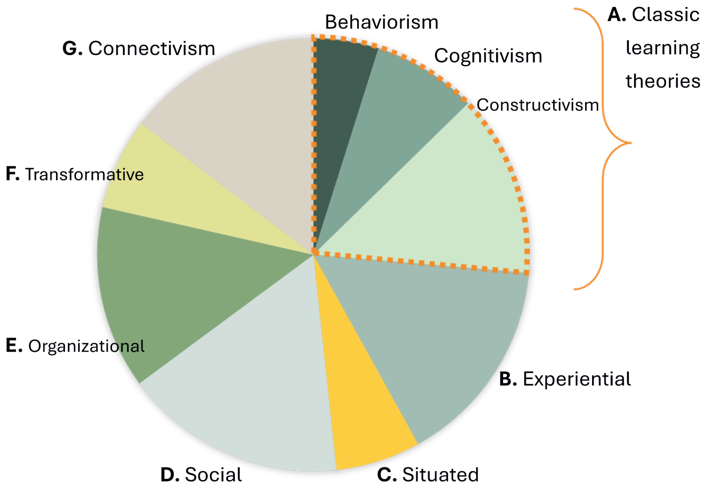

Figure 3.3.: Learning theories relevant to the characteristics of living labs.

The learning theories numbered (A-G) are summarized in Table 3.2 of section 3.4.1 and explained in detailed in the Appendix B (along with the insights on the need to connect these theories and the possible links between modern learning theories). Section 3.4.2 provides illustrative examples of how these theories have been used or can be operationalized in a living lab context, and Table 3.3 shows the relationship between the identified learning theories and living lab characteristics. Section 3.4.3 develops a living lab learning framework, based on Table 3.4, where Table 3.4 connects key concepts (italicized) in each learning theory with the components (bolded) of the learning framework. Section 3.4.4 then highlights the added value of the living lab learning framework.

3.4.1. RELEVANT LEARNING THEORIES

The learning theories identified as relevant to living lab characteristics, namely behaviorism, cognitivism, constructivism, experiential, situated, social, organizational, transformative, and connectivism are described in detail in the Appendix B, and summarized in Table 3.2, column 1. Table 3.2 further organizes these learning theories according to the three key questions posed in Section 3.3; "What type of knowledge is produced?", "How does learning occur within each theory?", and "Who is learning?". This categorization allowed identification of the learning types, processes and levels associated with each learning theory.

Table 3.2.: Summary of nine learning theories organized for three interacting components: learning types, processes, and levels.

	Theories	Summarized Explanation	Type (what)	Process (how)	Level (who)
A.	Behaviorism	Learning is a result of external stimuli leading to observable behaviors. Reinforcement and punishment shape behavior	Learning as an observable change in behavior (Conradie, 2014)	Stimulus-Response	Individual
	Cognitivism	Focuses on mental processes such as attention, memory, and problem-solving. Learning involves encoding, storing, and retrieving information.	New input information is processed in short- or long-term memory to produce learned output behavior (Jung, 2019)	Information Processing (Muhajirah, 2020)	
	Constructivism	Learners actively build understanding by connecting new information to existing mental structures	Construction of new knowledge building on previous ones; meaning construction based on personal experiences	Active Construction of Knowledge	
B.	Experiential	Learning involves a continuous cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation	emphasizes the practical application of knowledge from content- and learner-perspective	Reflection on Experience	It focuses on learning through individual or team's experiences, and less on social interactions
C.	Situated	Learning is situated in real-world contexts, and knowledge participation in meaningful activities within a community of practice	knowledge, skills, and tactics are coconstructed among peers through active engagement through social interactions and negotiations	Learning in Authentic Contexts (Curnow, 2022)	It shifts from a solely individual (cognitive activity) and regards learning as a process of participation in communities of practice
D.	Social	The first approach defines learning as observations, interactions, and communication within social situations (Conradie, 2014). This theory centers around the idea that individuals create knowledge socially through shared experiences	It argues that social and cultural values and practices play a key role in fostering learning within a group by sharing common environmental and experiential factors	Observational Learning & Modeling (Vygotsky, 1978)	Early work is conceptualized as individual learning influenced by imitating other's behaviors & attitudes; the latter approach highlights the role of the social or cultural environment in learning
E.	Organizational	Involves making adjustments and improvements within the existing organizational framework (single-loop) and questioning underlying assumptions and values (double-loop) (Dutta & Crossan, 2005)	focuses on understanding knowledge acquisition, creation, retention, and transfer in organizations (Crossan et al., 1999)	Single-Loop and Double-Loop Learning	Situated in the learning activities of individuals, teams, and (inter)organizational networks; multilevel where different processes link the individual to group and organization
F.	Transformative	Involves a profound shift in an individual's perspectives, beliefs, and assumptions. Learning occurs through critical reflection and a reevaluation of one's worldview.	It offers a framework for understanding how individuals can undergo profound shifts in their perspectives, beliefs, and actions.	Perspective Transformation (Gamache et al., 2020)	Approaches learning as the process of reinterpreting one's habits and opinions
G.	Connectivism	Defines learning as connections to a network of knowledge that can include any form of interaction (G. P. Hendricks, 2019; Masethe et al., 2016)	Shift to new ways of self-regulated learning through networks and databases on different e-learning platforms	Networked Learning	Connections and networks with other individuals, information, resources, and technologies

3.4.2. A brief overview of learning theories in living lab methods and activities

As mentioned at the start of section 3.3, only four papers specifically outline the application of learning theories in living labs, with social learning theory applied thrice, experiential applied twice, and situational and transformative each applied once. Further, in practice, many activities in living labs, such as peer-led learning, field experiments, workshops, seminars, open (online and offline) communities, and communities of practice (COP) (Huang and Thomas, 2021), are grounded in one or more of these theories. This section provides a brief insight into a few common living lab activities and how they embody different learning theories (annotated A to G) without seeking to be comprehensive. Furthermore, the relationship between selected learning theories and living lab characteristics is detailed in Table 3.3.

A. Participants in all living labs learn through exposure to diverse knowledge, engage in individual cognitive mental processes such as information processing, comprehending, and memory-based learning, as described in the classic learning theories.

B. Collaborative learning activities in living labs put more emphasis on experiential learning theory (Daniels and Walker, 1996). They emphasize hands-on experiences and reflection through exploration and experimentation to solve real-world problems through field trips, experiments, and trials, founded on experiential learning theory (Huang & Thomas, 2021; O'Brien et al., 2021).

C. Situational learning is evident in living labs that employ methods such as COP and ethnographic studies (Tusting and Barton, 2003). Elements of situated learning theory, such as embeddedness in realworld contexts, adaptive learning, and active participation, can be observed in living labs (van der Horst & Staddon, 2018).

D. Living labs demonstrate social learning through participative, collaborative, and co-creative processes through methods such as brainstorming activities, workshops, peer-led working groups, and so on. Social learning theory, as highlighted by Blezer et al. (2024) and Knickel et al. (2023), supports community collaboration and shared learning experiences in living labs.

E. Many living labs operate at a long-term organizational level. Further, various representatives from public and private sectors, research institutions, and civil society co-create in living labs, communicate, and make decisions within an organization-like-setting. Organizational learning unfolds at individual, team, and organizational levels, where actors can improve their existing framework, reevaluate their assumptions, and transfer insights gained from living labs back to their organizations and other contexts.

F. Transformative learning in living labs encourages reflection and perspective shifts, fostering empowerment among participants. Living labs are often used strategically to advance transitions toward sustainable policies. Such transitions require changes in personal and societal perspectives, beliefs, or behaviors and can be achieved through transformative learning (Corazza et al., 2018).

G. When designed as an innovation network, living labs align with connectivism learning theory. They often facilitate participation in digital spaces, online communities, and virtual or augmented realities (Bhatta et al., 2024), connecting individuals to diverse information and expertise.

Some living labs are guided by design-based learning (Brankaert & den Ouden, 2017; Trei et al., 2021), action-research, citizen science (Oliveira, 2022; Willis & Gupta, 2023), problem- or project-based learning, and game-based learning, (Borgford-Parnell et al., 2010; Moffett & Cassidy, 2023; Taajamaa et al., 2013). These approaches appear to be a natural fit for living labs with their emphasis on usercenteredness, agile, iterative approach, digitalization, and/or transversal skills (Koens et al., 2024). However, these newer concepts have their foundations in the existing learning theories. For example, game-based learning is grounded in social-constructivism (Moffett & Cassidy, 2023), project or problem-based learning is grounded in experiential, and constructivism theories (Borgford-Parnell et al., 2010; Taajamaa et al., 2013), while action research is grounded in experiential, transformative and constructivism learning theories (Matsekoleng, 2021; Zunariyah et al., 2018).

Table 3.3.: Relationship between selected learning theories and living lab characteristics, bold highlights the most prominent relationships.

	Real-life setting	Pursuit of Innovation	User-centered	Co-creation in multistakeholder	Digitalization	sustainability
Experiential LT (Masethe et al., 2016; Quay, 2003)	**Learning happens in real-world setting through iterative hands-on experiences, e.g. prototyping water-saving measures in a living lab**	**Encourages iterative learning through experimentation, guided by feedback loops that drives innovation in LL, e.g., product development**	**Users participate in designing experiments and reflecting on their outcomes. E.g., users try out a new soil health app and suggest and refining points**	Thrives on diverse perspectives during observation and experimentation phases	Modern tools, such as virtual reality simulations, enhance experiential learning	Reflective cycles may promote sustainable practices by evaluating impacts; help adapt solutions for long-term viability
Situated LT (Curnow, 2022; Eddy et al., 2019)	**Learning is context dependent occurring in authentic, realworld situations such as, improving urban ecosystem services (place-based)**	Problem solving may arise in authentic situations, thus, fostering innovation	**Learners actively engage as practitioners, not just passive recipients, and their needs are at the core of activities**	**Involves diverse participants interacting in and between multiple contexts where new learners move from peripheral towards full participation/ ownership**	Technology facilitates access to situated contexts, e.g., maps for a certain geographical area, hydrological models, etc.	Promotes sustainability through solutions that are tailored to environmental and social contexts
Social LT (S. K. Gibson, 2004; Rannikmäe et al., 2020)	Social interactions happen naturally in real contexts that are interactive, e.g. Peer-to-peer learning	**Group dynamics and social interactions encourage the emergence of creative ideas and innovative solutions**	**The needs and contributions of users (actors) play important roles in continuous, reciprocal interactions**	**Diverse social actors such as citizens, researchers, and industries collaborate and contribute to the learning process**	Digital platforms enhance interaction, engagement, & support shared learning experiences	Shared learning may foster sustainable behaviors
Organizational LT (Argote, 2012; Dutta & Crossan, 2005; Hafit et al., 2022)	Learning happens within real-life organizational ecosystems, e.g. learning during stakeholder general meetings	**Organizational culture fosters collaboration and generation of new ideas (Hafit et al., 2022)**	Allows users (employees/ actors) to build on already-existing competencies as their advancement is linked with that of the organization's	**Cross-departmental and cross-sectoral collaboration is reflected in long-term living lab organizations**	Technology facilitates learning through data analysis & collaborative platforms	**Adaptive learning in organizational setting is linked with long-term sustainability orientation, scalability, & transferability**
Transformative LT (Mezirow, 2018; Singer-Brodowski, 2023)	Transformative experiences occur in authentic contexts, e.g. experiments on climate-resistant alternative crop types	**Engaging in critical think helps shift/ adapt perspectives and foster innovative thinking (Singer-Brodowski, 2023)**	Learners drive their own transformative process by re-evaluating their beliefs, values and assumptions	Dialogue with diverse groups enriches the reflective process with transformative learning	Technology assists reflective practices as information becomes accessible across time or geographical boundaries	**Perspective shifts often involve sustainability themes and transition**
Connectivism LT (G. P. Hendricks, 2019)	Networks integrate real-world and virtual environments	Information exchange across networks creates environment for innovation	Learners actively navigate networks, tailoring their experiences to their needs	Networks connects diverse contributors	**Many LL make use of digital technologies to facilitate co-creation and enhance engagement**	Connective learning can support knowledge sharing for global sustainable practices
Classical LT	Living labs involve **formal learning and skill development** through presentations, trainings, and other similar activities that require familiarizing, memorizing, and understanding information that can be explained under classic LT					

3.4.3. ANALYTICAL LIVING LAB LEARNING FRAMEWORK

A learning framework serves as a tool or guideline that helps recognize learning and align activities and experiences within a specific learning environment toward a clearly defined goal (Travers et al., 2019). A learning framework does not dictate what should be learned, as it is not a standard. Instead, it facilitates the configuration of learning environments to enhance their innovation capacity, problem-solving, and continuous improvement for long-term sustainable impacts.

In this section, we build on the insights from learning theories in 3.4.1, using the three major questions from Section 3.3; "What type of knowledge is produced?", "How does learning occur in a specific learning theory?", and "Who is learning?". This analysis led to Table 3.2, which categorized the learning theories into three interacting components: learning types, processes, and levels. These components were further themed into subcomponents and presented in Table 3.4. Together, these components led to the development of an analytical living lab learning framework, shown in Figure 3.4. This framework allows identifying the nature of the knowledge acquired, the processes through which learning occurs, and the entities involved in learning within living labs, thereby allowing to capture living lab outcomes beyond their immediate results.

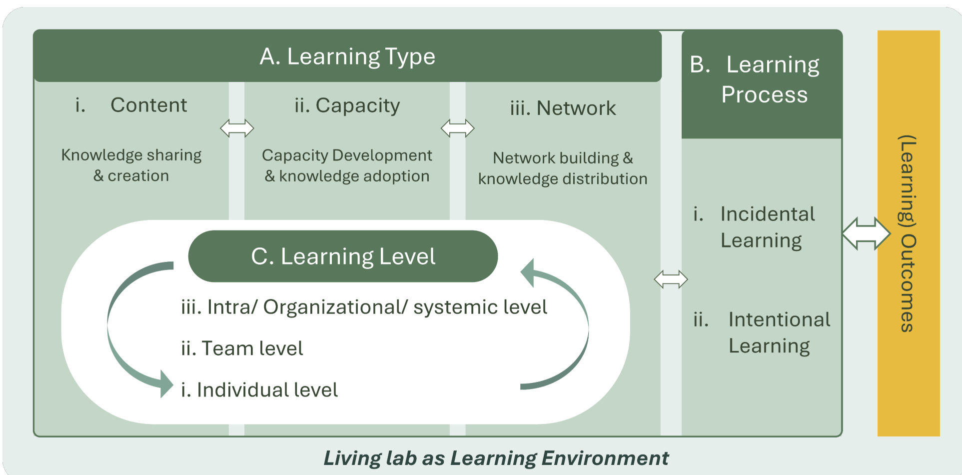

Figure 3.4.: Analytical learning framework for living labs as a learning environment.

A. **Learning types**

'Learning types' refers to understanding the different forms of knowledge shared and created in a co-creative environment. Different learning theories have a different take on the type of learning. For instance, cognitive learning emphasizes internal understanding of certain concepts, while situated learning focuses on interaction within networks and practical know-how. Similarly, experiential learning focuses on acquiring knowledge and skills through practical application, whereas social learning is based on forming an understanding through social interactions. In this light, the framework categorizes learning types into content, capacity, and network learning (see Table 3.4).

Content learning is the act of acquiring substantiative knowledge on a specific concept or subject. It encompasses sharing knowledge regarding a certain subject and creating new knowledge within the co-creation environment. It relates to being able to retain facts (or assumptions) and comprehend the information, leading to knowledge creation and can be acquired by employing classic learning theories. This type of learning takes place both actively and passively (Vreugdenhil et al., 2010) during observation, presentations, lectures, discussions, reports, and so on. Rukspollmuang and Chansema (2024) apply a living lab to promote such content learning in a campus setting.

Likewise, the act of being able to apply substantive knowledge and skills in real-life is understood as *capacity learning*. Living labs that aim for capacity development, as described by Frick-Trzebitzky et al. (2022), exhibit capacity learning. Primarily observed within experiential, situated, and transformative learning theory, this learning enables the application of shared or created information, methods, or concepts in existing and new situations and aids in decision-making by selecting certain approaches based on context. Capacity learning occurs during field experiments, serious games, co-creation workshops, and so on, where actors practice skills in real-life or simulated scenarios (Huang & Thomas, 2021).

Network learning includes understanding the behavior, priorities, and values of relevant actors and information to engage meaningfully. This knowledge enables stakeholders to communicate in ways that resonate with each other's perspectives and motivations, thereby enhancing the impact of co-creation efforts (Andrade et al., 2022), and contributing to innovative spin-offs, iteration and upscaling (Soetanto & van Geenhuizen, 2011). Primarily arising within situated, social, and connectivism learning theory, it focuses on effective collaboration, developing trust, finding common ground, and forming alliances. Network learning occurs in both formal and informal activities, including workshops, COPs, co-designing activities, co-working spaces, meetings, social gatherings, and digital platforms.

B. **Learning processes**
'Learning processes' refers to understanding 'how learning is taking place' in a co-creative environment. While knowledge production can be an outcome of a living lab, it is itself a process, not a singular event. Different learning theories offer distinct perspectives on the learning process, each emphasizing diverse factors. For instance, experiential learning focuses on reflection on experiences, social learning emphasizes observational learning and modeling, and transformative learning involves perspective transformation (Kørnøv et al., 2022; Light, 2006). Here, a pragmatic stance on learning processes as intentional (i.e., formalized) or incidental (i.e., ad-hoc) is adopted (Table 3.4).

The *intentional learning process* can be understood as deliberate learning facilitated by implementing diverse tools, methods, and approaches to achieve planned outcomes. Research on living labs highlights the significance of planned and deliberate action (Barraclough et al., 2023; Du Preez et al., 2022; Palgan et al., 2018). Within living labs, various methods are purposefully employed based on the context, prerequisite, available resources, and expected results (Bhatta, Vreugdenhil, & Slinger, 2023). Huang and Thomas (2021) identify a few of these methods as co-creation workshops, user committee meetings, design thinking, virtual engagement community, and world café. Several other tools and methods, such as brainstorming tools, think bootcamp, COP, serious games, and action research, are utilized in living labs to realize intended learning outcomes.

Incidental learning is central to adult learning (Marsick & Watkins, 2001). This process involves unintentional or unplanned learning that occurs as a byproduct of organized activities or experiences (Marsick & Watkins, 2001). As an experimental and iterative process, a large part of knowledge acquisition in living labs happens unexpectedly or incidentally (Lehmann et al., 2015). This depends on the cognitive ability of actors and how they absorb information from their environment without explicitly intending to do so. Incidental learning can occur in formal or informal social interactions and real-life experiences rather than through deliberate instruction or a planned approach. The living lab environment fosters interdisciplinary and multisectoral activities, exposing participants to diverse perspectives, observation, and reflection, thereby creating opportunities for unanticipated learning moments. Accordingly, living labs have been recognized as cultivators of ‘serendipity’ (Jaśkiewicz & Smit, 2024; Sauer & Copeland, 2021).

C. **Learning levels**

‘Learning levels’ aim to identify different levels of learning ranging from the individual (micro) level to the societal (macro) level in a co-creative environment. While many learning theories, including classical theories, focus on learning at the individual level, one person alone is not able to embody the breadth and depth of knowledge necessary to comprehend complex societal issues (Tyre & Von Hippel, 1997). While individual learning is valuable for assessing and enhancing the impact of co-creative projects through specialized knowledge sharing, collective learning at group, organizational, and social levels is essential for its practice and dissemination (Sánchez & Mitchell, 2017). Therefore, learning in a co-creative environment needs to occur at multiple levels: *individual* (for personal growth and learning), *team/group* (for peer-learning, synergy, and collective intelligence to achieve intended outcomes), *inter-team/ organizational* (for adaptability, goal alignment, and knowledge dissemination at a wider organizational level), and systemic (wider) level. These levels, while seemingly distinct, are interrelated, where one level feeds to another, resulting in a learning ecosystem, improved decision-making, and enhanced resilience and flexibility.

Different learning theories focus on different levels of learning (Table 3.4). Cognitive and experimental learning occur primarily at the individual level, whereas social learning occurs during the interactions within and between teams (de Kraker, 2017). Likewise, transformational learning can occur from individual to systemic (societal) level (Boström et al., 2018), whereas organizational learning clearly highlights the different levels of learning as individual, team/group, and organizational (Dutta & Crossan, 2005; Huber, 1991; Von Zedtwitz, 2002). Individual actors learn through intuition (recognizing patterns) and interpretation of information from various sources, while a team/group learns through integrating individual knowledge to develop a shared understanding in order to achieve the intended innovative goals. At the organizational level, learning involves institutionalizing knowledge produced by individuals and teams and embedding it within the organization's system to systematically exploit learning (Crossan et al., 1999). In line with Schuurman (2015), analyses of living labs can be conducted at the macro, meso, and micro levels. The macro-level deals with the long-term organizational structure through quadruple helix partnerships, the meso-level is project-specific innovations, and the micro-level encompasses the specific methods and everyday individual activities employed in the living lab. These categorizations can be related to the learning levels of the analytical framework. Living labs, however, are often established as temporary structures, which affects the long-term adoption of their outcomes and their transformative impacts. Nevertheless, since participants in living labs come from diverse sectors and represent various organizations, learning created in these labs may still transcend the living lab environment, influencing other organizations and sectors. To fully realize the transformative potential of living labs at systemic level, emphasis should be placed on designing them as long-term initiatives, supported by plans for sustained operations such as, stable funding models, governance structures, and strategies for continuous engagement and integration (Chroneer et al., 2019).

Table 3.4.: Explicating connections between the concepts *(in italics)* of the learning theories and the living lab learning framework components **(in bold)**

	Theories	Learning Types	Learning Process	Learning Level
A.	Behaviorism	**Content** (acquiring factual and conceptual knowledge): *Emphasizes acquiring specific behaviors, responses, and skills; Learning as an observable change in behavior* (Conradie, 2014)	*Learning* is **intentional**, *occurring through structured conditioning and reinforcement (Stimulus-Response)*	**Individual:** *Primarily focused on the individual's behavior change* (Muhajirah, 2020)
	Cognitivism	**Content**: *Focuses on acquiring knowledge and organizing it in mental structures; information processed in short- or long-term memory to produce learned output behavior (Jung, 2019)*	**Deliberate** *mental processes are used to acquire knowledge (Muhajirah, 2020)*	**Individual**: Focuses *on the individual's cognitive processes (Jung, 2019; Muhajirah, 2020)*
	Constructivism	**Capacity** (application of knowledge and skills): *Focuses on understanding & applying content knowledge through experience; construction of new knowledge and meaning construction building on previous experiences*	*Active,* **intentional** *knowledge construction through engagement with tasks (Harasim, 2017; Jung, 2019)*	**Individual + Team:** *Individuals construct knowledge through social interaction, but it can extend to team-based problem-solving*
B.	Experiential	**Capacity:** *Emphasizes the practical application of knowledge from content- and learner-perspective; Involves learning by doing—applying knowledge in a practical setting (Kolb et al., 2014; Quay, 2003)*	*Learning can occur both* **intentionally** (*structured experiences)* & **incidentally** *(through reflection on unplanned experiences) (Masethe et al., 2016)*	**Individual + Team:** *Individuals and teams learn by doing and reflecting on their experiences (Kolb et al., 2014)*
C.	Situated	**Capacity + Network:** *Learning involves gaining practical skills and understanding the norms and practices of a community; Skills, knowledge, and tactics are co-constructed among peers through engagement in social interactions and negotiations (Curnow, 2022)*	**Incidental** *and embedded learning that happens in authentic social contexts (Curnow, 2022)*	**Team + organizational:** *Learning occurs in social teams and broader organizational systems like communities of practice, shifting from a solely individual (cognitive activity) (Tyre & Von Hippel, 1997)*

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Table 3.4 – continued from previous page

Theories	Learning Types	Learning Process	Learning Level
D. Social	**Network** (learning from actors, relationships, and systems): *Social and cultural values and practices play a key role in fostering learning within a group by sharing common environmental and experiential factors (Reed et al., 2010; Vygotsky, 1978)*	*Learning occurs as a* **byproduct** *of observing others during interactions (Vygotsky, 1978)*	**Individual + Team + broader**: *Individuals learn within teams and broader societal systems; Early work is conceptualized as individual learning influenced by imitating others (Bandura & Walters, 1977); the latter highlights the role of the social or cultural environment (Bruner, 1996; Rannikmäe et al., 2020)*
E. Organizational	**Content + Capacity:** *Focuses on acquiring knowledge that can be applied to improve organizational practices; understanding knowledge acquisition, creation, retention, and transfer in organizations (Crossan et al., 1999; Dutta & Crossan, 2005)*	**Purposeful, systemized** *learning within organizations in single-Loop, double-Loop, and triple-loop Learning (Argyris & Schön, 1996; Pahl-Wostl, 2015)*	**Organizational:** *Situated in the learning activities of individuals, teams, and (inter) organizational networks; multilevel where different processes link the individual to group and organization (with focus on organization)*
F. Transformative	**Capacity:** *Learning involves applying knowledge in a way that transforms one's perspectives and behavior; offers a framework for understanding how individuals can undergo profound shifts in their perspectives, beliefs, and actions (Mezirow, 1993, 2018)*	**Intentional** *reflection and re-evaluation of beliefs and assumptions and perspective transformation (Gamache et al., 2020)*	**Individual + broader system:** *Individuals undergo transformation, but it can also lead to broader societal change (Gamache et al., 2020)*
G. Connectivism	**Network:** *Navigating and engaging with a network of information, ideas & people; self-regulated learning through networks and databases on different e-learning platforms (G. P. Hendricks, 2019; Masethe et al., 2016)*	*Learning happens* **organically** *through navigating, connecting, and engaging with a network of information sources (G. P. Hendricks, 2019)*	**Team + intra-team + broader system**: *Learning occurs within a networked, digital environment, often across systems and connections with other individuals, information, resources, and technologies*

3.4.4. ADDED VALUE OF THE LIVING LAB LEARNING FRAMEWORK

The living lab learning framework aims to support the design, monitoring, and evaluation of learning within living lab activities, helping to recognize the outcomes and impacts that extend beyond immediate results (Box 1). Its three learning components, along with their sub-components, serve as foundational building blocks, offering a structured approach to organizing and tracking learning activities in living lab projects in relation to the outcomes. This framework can be applied either in full or in part during various project phases: initiation, implementation, and evaluation, depending on the specific learning objectives of the living lab. For example, it can improve the alignment of the content, resources, and activities for each task with the learning outcomes. The framework also supports the development of learning pathways within living labs and allows for reflection on participants' own learning processes, fostering deeper learning. The simplicity of the framework allows to accommodate a wide range of living lab types, each operating within distinct contexts and addressing diverse objectives.

When applied in the initiation phase, the framework helps align the project's learning goals with the overall project design while guiding participants in identifying the types of knowledge required and the processes needed to achieve these goals. As such, it aids in determining activities that promote specific types and levels of learning. While incidental learning cannot be designed, the environment that cultivates such learning through experimental, situated, and social learning approaches can be planned. In the implementation phase, the framework can improve team coordination by facilitating the tracking of real-time learning processes, monitoring progress, and identifying learning gaps. It may also act as a quality control tool, ensuring that any deficiencies in learning are addressed and overall learning enhanced. Finally, in the evaluation phase, the framework offers a systematic method for assessing (learning) activities and outcomes, understanding impacts, and can even provide insights for the design of future living labs. The structured approach to evaluation, which draws on and blends multiple learning theories, not only highlights immediate results but also recognizes the critical role of learning in driving the long-term success of living lab projects, for example, through enhanced stakeholders' capacities and establishment of new collaborative networks. Indeed, since living labs prioritize iterative learning driven by continuous feedback loops, the framework is designed to be applied dynamically rather than statically.

BOX 1
Learning in a living lab environment: An example

A participatory, co-creative living lab setting aims to provide a holistic picture and develop a more realistic solutions to complex real-world issues by involving multiple stakeholders, such as citizens, private and government organizations, and academia. For example, in the context of sustainable land and waterscapes, a living lab might focus on goals such as mitigating regional droughts through application of nature-based solutions. To achieve these goals, activities such as brainstorming sessions, co-creative workshops, site visits, and experimentation of different measures are employed to assess the baseline, understand user needs, and identify effective measures. Such living lab environments facilitate learning on, (i) combining theoretical understanding and innovative know-how, (ii) engaging meaningfully in the appreciation of diverse perspectives and priorities, (iii) sharing disciplinary and practical knowledge in building a more comprehensive understanding of sustainable pathways for land and water systems, amongst others. The living lab learning framework can aid in connecting learning within such living labs to their outcomes and impacts that serve to extend their effects beyond immediate results, see Bhatta et al. (2025a).

3.5. Concluding remarks

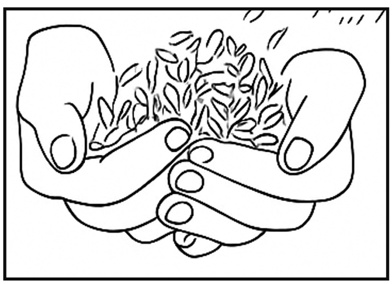
This paper positions living labs as an approach to deal with complex and interconnected problems, such as sustainable land and water management, and offer insights into how these labs can enhance their outcomes and impacts both within and beyond their co-creative environments by focusing on learning. To this end, a novel analytical living lab learning framework is developed to capture the often overlooked learning outcomes and to enhance the configuration of living labs as co-creative learning environments.

The first part of the study draws on literature to examine learning theories relevant to the characteristics of living labs with a focus on sustainability and cognizance of digitalization (see (Bhatta et al., 2024)). The nine learning theories identified are: behaviorism, cognitivism, constructivism, experimental, situated, social, organizational, transformative, and connective learning theories. The methods and activities commonly employed by living labs, including workshops, design thinking, serious games, action research, and knowledge dissemination, are found to have their foundations in these theories. Accordingly, the second part of the study develops an analytical living lab learning framework using these theories to provide an epistemological basis for living lab learning. The framework categorizes learning into: A. 'Types' referring to the nature of the knowledge shared and created, further classified as content, capacity, and network; B. 'Processes', understood as the method of acquiring learning, classified as intentional or incidental; C. 'Levels' concerning the entities involved in learning, classified as individual, team, organizational, and systemic. By applying this framework during initiation, implementation, and/or evaluation phases, living lab activities and methods can draw on a wider epistemological basis and can be aligned with the often-overlooked learning outcomes. Focus on learning in the living labs that tackle complex societal challenges not only enhances the impact of living labs as an approach but also improves the ability to address these challenges. While the learning framework developed in this research offers a systematic method for capturing learning within a living lab environment and is contextualized to living labs based on relevant literature, it can potentially be used in other co-creation contexts.

A limitation of our study is that we don't use an exhaustive list of living lab activities in relation to the learning theories, which could provide a topic for future studies. Further, we investigated learning theories with a primary focus on living lab characteristics but no other lab terms, such as innovation and policy labs. An in-depth examination of learning within these types of labs might yield wider insights. However, simply using the search term "learning" in combination with "living lab*" proved insufficient to capture the full spectrum of learning within living labs from multiple angles, as the term "learning" is often used more informally. For the keyword 'innovation', we only considered review papers because an unfiltered search returned an overwhelming number of 865 papers in Scopus alone. To manage this, we intentionally restricted the analysis to review papers. Although these papers may include summaries of empirical findings and provide an overview of existing evidence on applied learning theories, the lack of direct exploration of learning theories within the context of innovation research remains a limitation. This study responds to the need for epistemic clarity in living labs by offering a theoretically grounded learning framework. However, as living labs are inherently transdisciplinary and rooted in practical, real-world contexts, applying this framework in empirical case studies is necessary to validate and further contextualize the framework, and to strengthen its use in enhancing the effectiveness and impact of living labs. Although Box 1 offers a brief insight into the practical applicability of the framework, in-depth case studies remain essential for full implementation of the framework.

4

HARVESTING LIVING LABS OUTCOMES THROUGH LEARNING PATHWAYS



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ABSTRACT

Pressure on land and water systems is a major sustainability challenge faced by modern society. Living labs have emerged as a collaborative approach that fosters innovative solutions to address such complex issues. Living labs facilitate innovation by continuous exchange of knowledge and experiences amongst actors from diverse disciplines and sectors. Despite the occurrence of mutual learning and interaction in these co-creative, transdisciplinary environments, the impacts of learning on the participating actors and broader society are often neglected. This paper aims to identify learning occurring within a sequence of co-creative activities using 'learning pathways'. A 'living lab learning framework' is employed to systematically organize and categorize learning activities leading to outcomes, and to infer learning pathways. An ex-post analysis of an empirical case study on a climate adaptation project, named KLIMAP, was conducted. Seven learning pathways were distinguished, focusing on 1) harnessing collective, integrated knowledge, 2) building collaborative networks, 3) enhancing stakeholder capacity, 4) knowledge adaptation and contextualization, 5) knowledge diffusion, 6) co-creation facilitation, and 7) reflection and learning. The learning activities associated with each pathway are categorized into type, process, and involved entities, and the outcomes resulting from these activities. Finally, insights regarding activities to strengthen learning pathways and the impacts of future co-creative projects are distilled.

4.1. INTRODUCTION

Our water and land systems lie at the heart of some of the most pressing sustainability challenges, such as climate change, water scarcity, intensive agricultural practices, nature conservation, and resource conflicts (Ingrao et al., 2023; Meyfroidt et al., 2022; Rodell et al., 2018). These systems represent complex societal challenges, and managing them requires long-term, strategic, and collaborative planning (Haddeland et al., 2014; Karimi et al., 2018). In response, many water and land management practices are increasingly adopting sustainable development principles and fostering collaboration across diverse sectors, disciplines, and stakeholder groups, aiming to integrate innovations into society, policy, and governance (Bhatta, Le, et al., 2023; Larsson & Holmberg, 2018). In recent years, living labs have emerged as a transdisciplinary approach to tackling environmental challenges through innovative solutions (Peña-Torres & Reina-Rozo, 2022; Unger et al., 2022). Conceptualized as "a milieu (ecosystem, arena), a methodology, or an approach" (Bergvall-Kåreborn et al., 2009) or an "innovation network" (Leminen & Westerlund, 2012), living labs may take the form of physical spaces, platforms, or interaction spaces (Zingraff-Hamed et al., 2020). They have proliferated across geographical domains—such as campuses, rural and urban areas, and across application domains—such as energy, healthcare, and land and water management (Bhatta et al., 2024, p. figure 2). Tailored to specific applications, living labs drive innovation through co-creative activities within a network of public organizations, private organizations, academia, and civil society (Bhatta, Vreugdenhil, & Slinger, 2023; Hermans et al., 2013). The exchange of knowledge and experiences among these diverse actors establishes a strong foundation for cross-sectoral and interdisciplinary understanding of the challenges, leading to effective and innovative solutions (Castán Broto et al., 2022; Roux et al., 2017). Indeed, continuous mutual learning and interactions among stakeholders are vital in shaping innovative solutions (Boaz et al., 2018; Metz et al., 2019).

Although widely used as an approach to innovation, living labs rarely highlight the role of learning in co-creation (Bhatta et al., 2024). Often, co-creation is seen as a 'virtue in itself' with little to no attention to how it drives innovation (Dekker et al., 2021; Voorberg et al., 2015). Further, living lab impacts are usually assessed by their direct and tangible results, overlooking the significant outcomes emerging from learning activities and interactions (Bhatta et al., 2024; Lux et al., 2019). Yet, learning within living labs contributes to a broader understanding of the subject area, increases cross-sectoral engagement, and supports network-formation, value-creation, and scaling-up of innovations (Pärli et al., 2022). Thus, recognizing and mapping learning in living labs can significantly enhance their innovation capacity by capturing valuable outcomes, fostering continuous improvement, and providing recommendations for future initiatives (Andrade et al., 2022).

Learning is not merely a single activity or a moment of action in the context of living lab projects. Instead, it is a continuous and iterative process that includes multiple activities that lead to specific outcomes (Viera Trevisan et al., 2024). This learning journey can be effectively captured through learning pathways (Harris et al., 2006). Learning pathways provide a structured approach to navigating and sequencing learning experiences and guide individuals and organizations through acquiring and refining their knowledge and competencies, leading to specific outcomes (Harris et al., 2006; Mphinyane, 2013; Ramsarup, 2017). In a living lab co-creative environment, these pathways include diverse activities, such as training sessions, co-creation workshops, user meetings, self-directed learning, and hands-on experiences (Huang & Thomas, 2021). Designing or mapping learning within living labs to distill such pathways can deepen understanding of the project's broader impacts, ensuring recognition of the full spectrum of learning activities leading to the outcomes. Indeed, a learning pathway is a pluralistic approach that attends to multiple levels intrinsic to learning across time (de Royston et al., 2020).

While a learning pathway can serve as a pragmatic way for a co-creative project to either design or map project outcomes, empirical research on learning pathways remains limited (De Smet et al., 2016). This gap is partly due to the lack of a consistent and relevant way of describing pathways in relation to the resulting outcomes (Janssen et al., 2008). A framework that aligns learning activities and experiences in a co-creative environment with their resulting outcomes can aid in developing learning pathways (Bhatta et al., 2024; Travers et al., 2019). In this paper, the living lab learning framework grounded in learning theories developed by Bhatta et al. (2024) is applied to distinguish learning pathways in an empirical case of climate adaptation in the Netherlands.

The selected case study is intriguing in that diverse stakeholders were involved in developing climate-adaptive solutions at the landscape scale in a multi-layered approach extending from local-level field experiments to regional transformative agendas. This living lab provided the empirical context in which learning pathways are explored. The paper is organized as follows: after this introduction, a theoretical section on the extension of the living lab learning framework by Bhatta et al. (2024) to address learning pathways is presented, followed by an introduction to the case study and the methods section. Then, learning in the empirical case study is categorized according to the framework, and learning pathways are drawn. Lastly, the concluding section summarizes the findings, identifies research limitations, and provides recommendations for future research.

4.2. THEORETICAL BACKGROUND ON THE LIVING LAB LEARNING FRAMEWORK

Participants in a living lab co-creative environment contribute a diversity of knowledge and expertise, making their interactions reciprocal and the benefits mutual (Napan, 2015). Thus, the roles of "novice" and "expert" are fluid and interchangeable, unlike in traditional learning environments. Although living labs may include expert-led workshops or capacity-building training, they do not maintain fixed learner-educator roles throughout the project (Bhatta et al., 2024; McCormick & Kiss, 2015). This creates a dynamic learning environment that prioritizes continuous co-learning and development in physical, virtual, or blended settings. A learning environment is understood as the physical and virtual interaction space between the learning participants (stakeholders), learning content, and learning tools (McCormick & Kiss, 2015). Within a learning environment such as a living lab, a learning framework can serve as a guide to identify and structurally categorize learning activities and experiences (Bhatta et al., 2024; Travers et al., 2019). It is applicable at different phases of the living lab, as,

- During the initiation phase (ex-ante), it facilitates designing and aligning learning activities to the project outcomes,
- During implementation (ongoing), it can aid in monitoring learning progress and identifying knowledge gaps
- During post-project evaluation phase (ex-post), it can be applied to map learning to recognize and enhance the outcomes systematically.

In this light, Bhatta et al. (2024) developed a living lab learning framework rooted in learning theories. They identify ten relevant learning theories—behaviorism, cognitivism, constructivism, experimental, situated, social, organizational, transformative, and connectivism—based on the characteristics of living labs. These theories are explored through three key questions; “What type of knowledge is produced?”, “Who is learning?” and “How does learning occur?”. The insights are synthesized into an analytical living lab learning framework with three interacting components: ‘Learning Type’ (what), ‘Learning Process’ (how), and ‘Learning Level’ (who), which are connected to learning outcomes, as shown in Figure 4.1.

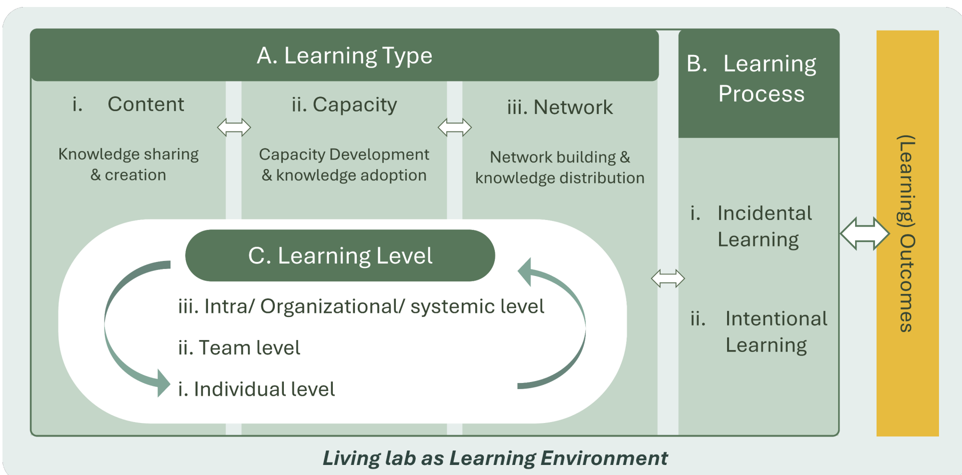

Figure 4.1.: Analytical learning framework for living labs as a learning environment; adapted from (Bhatta et al., 2025b)

In the framework, ‘Learning Type’ refers to the nature of the knowledge shared and created; ‘Learning Process’ is understood as the method of acquiring learning; and ‘Learning Level’ relates to the entities involved in learning. The ‘Learning Type’ is categorized as content, capacity, and network, where content involves acquiring substantive knowledge on a specific concept or subject area; capacity involves applying content knowledge and acquiring skills in real-life, and network involves understanding the behavior, priorities, and values of relevant actors to engage meaningfully with them. The 'Learning Process' incorporates various ways of engagement, such as cognitive activities (cognitivism and constructivism learning theory), learning-by-experiencing (experiential and situated learning theory), learning-by-interacting (situated and social learning theory), and learning-by-reflecting (transformative learning theory). The learning process is classified as intentional and incidental, where intentional is understood as deliberate learning facilitated by implementing diverse tools, methods, and activities to achieve planned outcomes, and incidental involves unplanned learning that occurs as a byproduct of other activities/experiences. While incidental learning can't be pre-designed in a project, it can be monitored through ongoing reflection and can be mapped after the project's completion. Likewise, 'Learning Level' is classified as individual, team, organizational, and systemic level learning.

The three learning components and their composite elements (sub-components) can be building blocks in designing, mapping, and monitoring learning pathways toward outcomes within empirical living lab projects. Indeed, living lab projects may be viewed as comprising a series of project activities with specific outcomes. Such activities are designed to enable and promote collaboration. They are often described using a variety of terms, including participation, co-creation, stakeholder engagement, joint knowledge sharing and creation, and more (d'Hont, 2020). In this approach, each pathway connects elements from the learning process, learning type, and learning levels to outcomes to distinguish the learning occurring within a particular living lab co-creative activity.

While many learning pathways are possible (Appendix C, Supplementary material for chapter 4), they do not necessarily unfold within a single co-creative project. Thus, it is both impractical and unlikely for a qualitative study to capture the vast variety of possible learning routes. Instead, a pragmatic approach to mapping learning pathways is to start with a focal component of the framework. For example, if the outcomes of unintentional learning are of interest, then the analysis could focus on activities in which unintentional learning occurred and identify their associated learning types and learning levels. Similarly, if the sphere of influence of learning or scaling-up of outcomes is of interest, then the analysis could focus on activities with distinct learning levels and identify their associated learning process and learning types. Likewise, if the outcomes from different learning types are of interest, then the analysis could focus on activities with different learning types and identify their associated learning process and learning levels. In this way, activity-specific learning pathways, comprising combinations of learning type, learning process, and learning level, may be mapped. When activity-specific learning pathway is mapped for unique learning type (Figure 4.2), the associated learning process can be either intentional, incidental, or both, and learning level can be either individual, team, organization, any two of them, or all of them. These distinct combinations form unique learning pathways. In this case, the pathways are unique to the learning types yet may vary in the learning process and level. No two activity-specific pathways mapped in this manner can exhibit the same learning type category, but they may exhibit similar learning processes or learning levels.

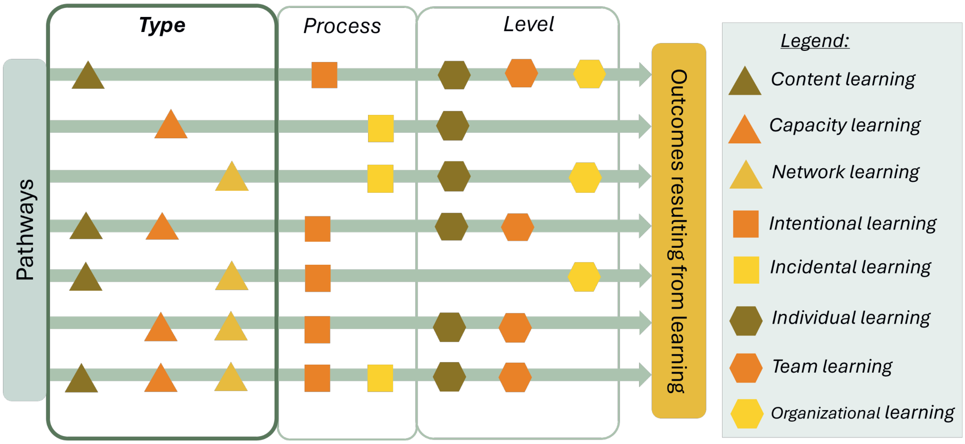

Figure 4.2.: A complete set of activity-specific learning pathways, built by focusing on learning types.

4.3. Case and Method

Addressing complex societal challenges requires more than just academic insights; it necessitates the practical application of knowledge in real-world contexts. This calls for transdisciplinary research in a socially relevant problem field, where the collaboration between researchers and practitioners can lead to innovative solutions (Pohl & Hadorn, 2008). Thus, this paper adopts a case study as the method of gathering evidence in a real-life context (Flyvbjerg, 2006; Yin, 2003), where key findings on learning within the case study are explored by applying the living lab learning framework and presented via learning pathways. The following sections provide an overview of the selected case study and details of the methods employed in this research.

4.3.1. KLIMAP case study

KLIMAP (KLIMaat Adaptatie in de Praktijk/ Climate Adaptation in Practice) is a collaborative network researching how the water and soil systems in the high sandy soil landscape of the Netherlands can be designed for climate adaption. Due to their permeability, sandy soils are increasingly vulnerable to climate change effects, such as droughts and floods (Ladányi et al., 2021). The eastern and southern regions of the Netherlands, characterized by sandy soils, experienced severe droughts in the years 2018-2020 and 2022 (Bartholomeus et al., 2023; Rakovec et al., 2022). In the summer of 2021, extremely heavy precipitation affected many parts of the southern Netherlands (Lehmkuhl et al., 2022). In response to such extreme events, many projects are actively addressing these challenges at different scales in these areas, KLIMAP being one of them. From 2020 to 2024, KLIMAP collaborated with stakeholders from the regional authorities (provinces and water-authorities), private companies (farmer business owners, farmer organizations), and research institutes to generate insights on climate adaptation at the landscape level ("KLIMAP", 2024). KLIMAP focused on designing climate-adaptive sandy soil landscapes in six larger regions, termed 'case studies' through 'development pathways'. 'Development pathways' is a flexible planning tool for an uncertain future where multiple paths are designed towards a desired future, and steps are taken to identify a necessary set of different climate-adaptive measures for the short-term, mid-term, and long-term. These actions include technical measures, changes in spatial function, policy, and regulations. Experiments with some of these measures were conducted in more than 25 sites (Figure 4.3). The experiments broadly focus on diversifying crop types, improving water retention, or enhancing soil structure. The experiments developed relevant technical knowledge concerning the effects of interventions such as wet-crop cultivation, a mix of different herb types, and innovative drainage systems. Additionally, national and regional hydrological models and analyses were used to explore possible future trends. In sum, KLIMAP sought to develop innovative approaches for creating climate-resilient sandy landscapes and to support various organizations, particularly public organizations, in implementing these approaches.

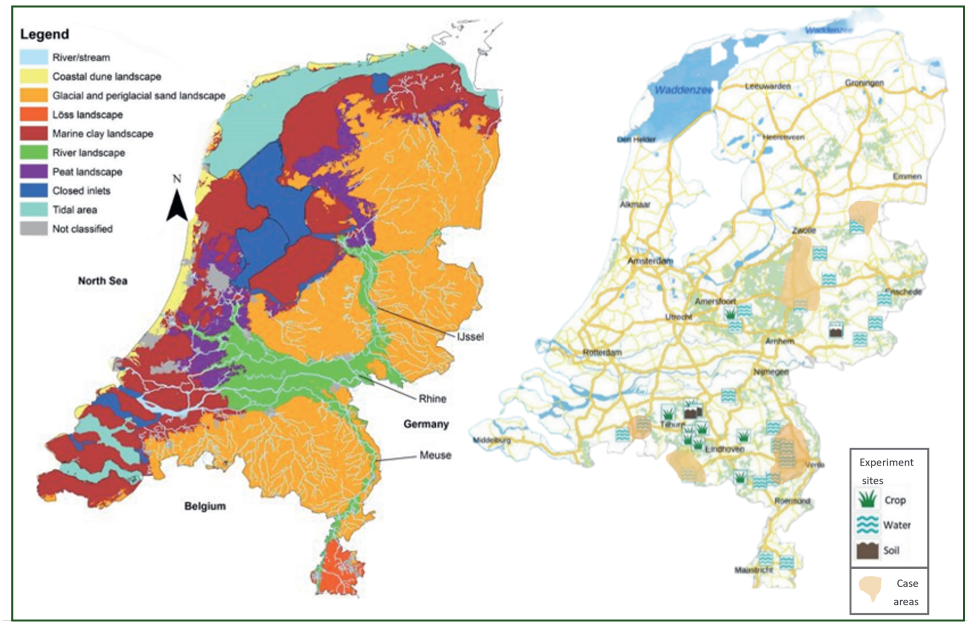

Figure 4.3.: Dutch landscape highlighting sandy landscape in the east and south of the Netherlands (left), KLIMAP experimentation sites, and case study areas (right).

Geographically embedded in the east and south of the Netherlands, as shown in Figure 4.3, KLIMAP embodies the core characteristics of a living lab (Bhatta et al., 2024; Hossain et al., 2019; Steen & Van Bueren, 2017). It explored, experimented, and evaluated climate adaptation measures and pathways in a real-world context through a "multi-stakeholder" approach within the Dutch governance system ("KLIMAP", 2024). The multi-stakeholder approach followed the quadruple helix model of collaboration, involving the public and private sectors, academia, and farmers; although individual farmers were not directly involved in co-creation, their interests were represented by farming groups. The innovative solutions developed within KLIMAP were co-designed in a flexible and iterative environment from diverse perspectives of stakeholders, where stakeholders and users played a central role.

The KLIMAP project contained multiple experiment sites and study regions that connected the field-level experiments to landscape-level development pathways. Thus, the single case study of KLIMAP was sufficiently broad to enable the mapping of learning pathways - the focus of this research (Yin, 2003). The research team followed the KLIMAP project for over two years. At the time of writing, KLIMAP had completed its research phase and was primarily focused on documenting and reporting its final findings.

4.3.2. METHODS

The research adopts a mixed method approach, including (i) Desk-based document analysis, (ii) Participation in workshops and meetings, (iii) Survey, and (iv) Interviews. The document analysis was conducted to understand KLIMAP's aim, design, inputs, activities, lessons learned, expected output, and outcomes. The analyzed documents comprised KLIMAP progress reports, documents on KLIMAP case studies, factsheets on the experiments, minutes of living lab meetings, and knowledge sessions from 2021 to 2024. No final living lab project reporting was analyzed, as this was not yet available. The document analysis facilitated capturing the project's progress timeline, experimental and case study locations, involved actors, co-creative activities, and the associated outcomes and learning. Additionally, the author(s) actively participated in several co-creative and brainstorming sessions on-site (N=3), community of practice (COP) meetings (N=2), and the final project symposium (N=1). The authors' involvement in these sessions can best be described as participatory and non-interventionist, as they neither acted as the designers nor the facilitators of the workshops and meetings.

A survey was conducted at the final KLIMAP symposium on 21st March 2024 with a relevant pool of stakeholders (N=26), where almost half (N=12) were external actors present only at the symposium, and the rest (N=14) were directly involved in KLIMAP (Appendix C). The surveys were conducted to gather the stakeholders' insights and reflections on the co-creation activities and outcomes of the KLIMAP living lab project. Survey respondents were asked to assess how various project activities contributed to the learning and outcomes of the project (only for KLIMAP respondents) and potentially to future projects (all respondents). The survey was conducted and analyzed using Qualtrics software, which complies with EU regulations by meeting the requirements of GDPR Article 28, which governs acquisition, processing, and storage of personal data.

Semi-structured interviews (N=12) were conducted with a selection of KLIMAP coordinators, work package leaders, field-experiment experts, and knowledge session facilitators, all of whom were actively involved in designing and conducting activities within the project (Appendix C). A widely applied method in qualitative research, the snowball sampling procedure (Goodman, 1961), was adopted in selecting the interviewees. The interview started with a small pool of known informants; they were asked to recommend further potential interviewees, leading to the full selection of interviewees. In the final selection, attention was paid to ensuring a good mix between sectors (e.g., agriculture, water management, knowledge management). In the semi-structured interviews, the discussion focused on what went well, what didn't, and why, aiming to capture strengths, limitations, and reflective learning on project activities. The interviews were coded using Atlas.ti data analysis software.

In analyzing the data, 32 key activities in the KLIMAP project were coded. The project activities were taken as the unit of analysis (d'Hont & Slinger, 2022; McEvoy, 2019). An activity is a combination of subject or material being addressed and the way in which it is organized or executed (McEvoy et al., 2018; Thissen & Twaalfhoven, 2001). The organizational aspects, such as the interactions and communication between participants, relate to the structure and flow of the activity. Meanwhile, the substance of the activity, like the knowledge or information shared and utilized, focuses on the material being addressed. Thus, an activity is a singular event, such as a workshop, that involves stakeholders in carrying out various actions aimed at jointly supporting problem-structuring, finding solutions, making decisions, or implementing (McEvoy et al., 2018). The project's activities were identified primarily from the interview data, document analysis and participatory observation.

These key activities were grouped with a primary focus on the "Learning Types" component of the living lab learning framework by Bhatta et al. (2024) to determine the learning pathways. This means that each activity was first categorized into one of seven unique learning types (Figure 4.2), namely: (i) content learning only, (ii) capacity learning only, (iii) network learning only, (iv) content and capacity learning, (v) content and network learning, (vi) capacity and network learning, or (vii) content, capacity and network learning.

Next, the learning process and learning levels associated with each of the seven activity-specific learning types were identified and coded. These distinct combinations form unique learning pathways. In this case, the pathways are unique to the learning types but may exhibit similar learning processes or levels. Some activities were coded in multiple pathways as they exhibited more than one learning type depending on their design and context. For instance, "workshop" is a common co-creation activity conducted numerous times with different goals within KLIMAP. When subjects dealt in a workshop led to substantive content knowledge, it was coded as content learning type, whereas when ways in which the workshop are organized within a COP helped refine one's understanding, enhanced their skills, and led to new connections, it was coded as content, capacity, and network learning.

As this study involved human subjects, the authors developed a data management and human ethics review plan in accordance with the requirements of the Delft University of Technology, as approved by the Human Research Ethics Committee under application number 106178, where all personally identifiable information (PII) was anonymized and processed confidentially.

4.4. Results

The following section identifies key activities undertaken in the KLIMAP living lab project. Each activity was categorized into one of seven unique learning types, described in section 4.2. Activities with the same learning types were grouped and linked to their corresponding outcomes. Table 4.1 highlights key activities, categorizes them into their respective learning types, and links them to their resulting outcomes and impact.

Table 4.1.: KLIMAP activities, their respective learning types, and resulting outcomes

	Activities	**"Learning Types"**	**Outcomes**
1)	Expert-led lectures and presentations, utilization of existing knowledge sources and platforms, operationalization of diverse field trials, sensor logs reports from the field trials, documentation of meeting-minutes, meetings reporting, co-creative workshops, and joint knowledge sharing and creation	*Content learning:* These activities allowed stakeholders to share and acquire substantiative knowledge on a specific concept or subject, e.g., climate adaptive measures and co-create new insights to further the knowledge	*New integrated knowledge, insights and lessons learnt:* Formation of joint-knowledge base, a catalog of climate adaptive measures for sandy soils divided into sub-regions (high grounds, flanks and stream valleys); production of numerous theses, papers, and policy briefs in relation to climate adaptation
2)	Identifying key stakeholders with stakes in the issue (snowball approach), reaching out and communicating to invite the relevant stakeholders, opening dialogues and exploration, establishing agreements on stakeholder organization's contribution, holding strategic planning sessions, mutually assigning roles within the living lab project, workshops to open dialogue around framing the challenge	*Network learning:* These activities enabled stakeholders to understand the importance of each other's perspectives, behavior, priorities, and thus, engage meaningfully with each other	*Formation of a collaborative network:* Improved trust and better understanding of sectoral interests and resources, leading to various new relations and projects, such as smaller internal collaborations, new projects such as CASTOR, NAT, Waterscapes, and Reshape (Figure 4.5)

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Table 4.1 – continued from previous page

	Activities	"Learning Types"	Outcomes
3)	Co-creative workshop/ sessions to design or apply diverse methods & tools to support working with development pathways across various case study regions: (i) Co-development and use of a "framework" to guide the exploration of development paths, (ii) Development & application of an "evaluation tool" to assess pathways and a "serious game" to an accessible experience to engage with the development path concepts	*Content and capacity learning:* These activities allowed stakeholders to acquire knowledge on diverse co-creative methods and tools and apply them in various real-life context within KLIMAP	*Capacity to use right tools in right way:* Improved readiness level in relation to application of development paths; Enhanced capacity to design & use diverse methods, frameworks and tools to guide practical exploration of climate-adaptive development pathways, evaluate them against selected criteria; Understanding on 'know-how'/ procedural knowledge
4)	Community of practice (COPs), co-creative workshops, and learning sessions that utilize techniques such as round table & table-swap discussion, virtual engagement, different co-creation techniques, learning and engagement activities, joint analysis, discussion on concepts, and feedback on methods and tools, to evaluate constraints and opportunities in different contexts and modify methods and tools accordingly	*Content, capacity, and network learning:* These activities allowed stakeholders to refine their understanding on diverse concepts, tools, co-creative methods; contextualize them in different situations; make new connections with other actors; and learn from peers	*Resituating knowledge in diverse contexts:* Refined framework and tools resulting from practical implementation in multiple contexts, new insights formation through participatory frameworks such as COPs, enhanced capacity to adapt knowledge and tools in diverse contexts, understanding on new perspectives and formation of new connections
5)	Activities to disseminate and upscale knowledge, via storytelling and blog writing in social media platforms, interviews in mainstream media channels such as newspapers and radio, podcasts, sharing preliminary and intermediate results in impactful magazines and project website, presenting results to wider network and advocacy to public bodies	*Content and network learning:* These activities enabled stakeholders to share the acquired substantive knowledge beyond the boundary of the living lab and engage meaningfully with other interest groups by leveraging both depth of content as well as the strength of the networks	*Knowledge & innovation dissemination:* Wider application of the knowledge created, and tools developed beyond the project's immediate boundaries nationally and internationally; increased collaboration and networking; improved awareness of climate-adaptive measures, potential impact on institutional and policy change

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Table 4.1 – continued from previous page

	Activities	"Learning Types"	Outcomes
6)	Designing effective communication strategies and operational guidelines, multiple methods to promote open dialogues and active listening, facilitating group discussions, creating inclusive environments, and providing additional support training	*Capacity and network learning:* These activities allow stakeholders to improve their own competencies but also leverage shared experiences and insights from a broader network	*Increased engagement leading to better decision making:* Improved trust and understanding, Informed decision making, better engagement, reduced miscommunication, improved inclusivity, deepened understanding of each other's values
7)	Goal setting and collective reflection on the process, self-reflection, continuous feedback and discussions, reporting and meeting minutes, recording experiences, using methods that have reflective elements to them, and (informal) participatory monitoring	*Capacity learning:* These activities enabled assessing and adapting the project process and interventions, with a focus on learning & reflection based on feedback and discussion	*Capacity to reflect, rectify and recommend:* Better understanding of project process, improved adaptability, insights for future projects, understanding on how actions interact with the broader system & how usual practices are embedded in the institutions

The respective learning process and levels for activities within all seven unique learning types are categorized as conceptualized in Figure 4.4. Based on the connection between these activities and their outcomes, seven distinct learning pathways were distinguished as described in Sections 4.4.1 to 4.4.7 and summarized in Figure 4.7.

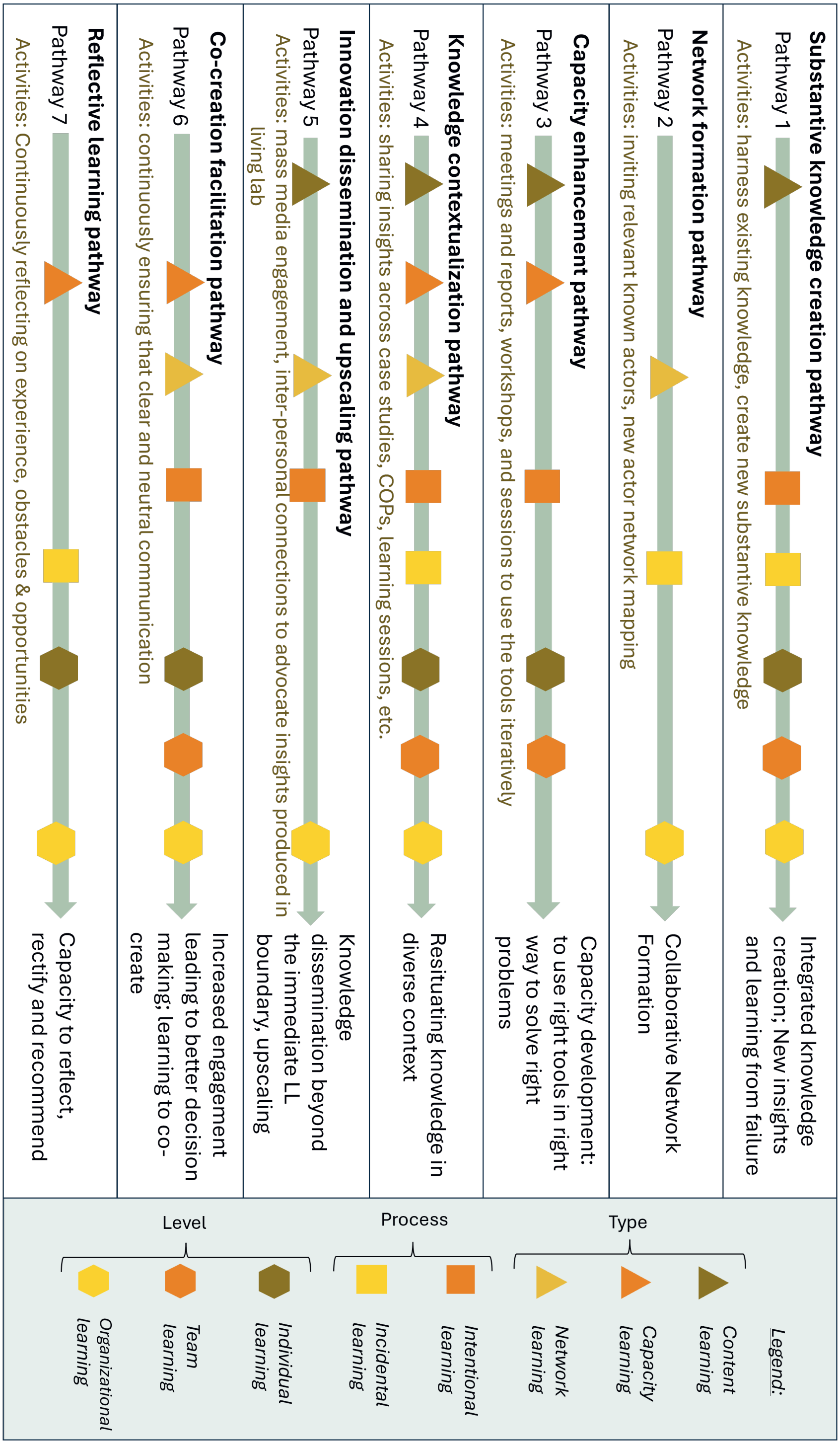


Figure 4.4.: Learning pathway skeleton focused on learning type component for KLIMAP.

4.4.1. PATHWAY 1: INTEGRATED SUBSTANTIVE KNOWLEDGE CREATION PATHWAY

This learning pathway emphasizes intentional co-development of content-specific knowledge on climate-resilient measures across all learning levels. A range of activities (Table 4.1)—such as expert-led lectures, field trials, and joint knowledge development—contributed to creating integrated substantive knowledge. Stakeholders were updated and connected through regular in-person, online meetings, and seasonal field experiment sessions with minutes recorded for each meeting. These activities were intentionally planned to facilitate the knowledge exchange and are formative in acquiring content-related insights on climate-adaptive concepts and measures.

Early in the process, the KLIMAP actors recognized the need to clarify, contrast, and connect new measures with existing practices in the region. Consequently, knowledge from national and institutional sources, literature, and policy documents were integrated with local insights, novel measures arising from field experimentations, and introduction of the 'development pathways' concept in the area. These measures consisted not only of physical interventions but also of policy and social interventions. A few field experiments included,

- introducing different species of earthworms in the soil,
- combating silting and compaction in the soil,
- determining crop evaporation by mixing diverse crop types,
- deep soil mixing, and wet agriculture (paludiculture) among others.

These measures were collectively developed and evaluated for their resilience to climate change, soil and water quality improvement, and ecosystem restoration. The concept of development pathways was theoretically explored in the case study areas. This concept was investigated to highlight possible strategic choices toward climate adaptation in sandy soil landscapes and identify the signals as to when to adjust the course of an existing strategy. KLIMAP theoretically investigated the concept of development paths to support decision-making and learn about the changing living environment and social needs ("KLIMAP", 2024).

The multi-perspective collaboration between the actors from diverse sectors and areas of expertise led to a unified knowledge management resource, namely the 'KLIMAP Menu'. This is a catalog of climate-adaptive measures for sandy soils that detail each measure's favorable conditions, degree of climate robustness, risks and opportunities, economic aspects, hydrological effects, and more.

Different combinations of these measures need to be applied coherently to address the effects of climate change. As the type of measures and their effectiveness depend on the water-soil interaction (groundwater table level), sets of measures were grouped into sub-areas, namely high grounds, flanks, and stream valleys. These sets of measures provide an overview of the effectiveness and applicability of adaptation measures in a specific (sub)area. The students, interns, and graduates who participated in the project produced numerous theses, papers, and policy briefs on climate adaptation. In the survey, 93% of participants from KLIMAP reported a better understanding of climate adaptation measures.

While many minor setbacks were gradually overcome with the lessons learned, the experiment on drip irrigation was considered a significant failure in KLIMAP. Intended to conserve water in sandy soil during dry summers, the experiment failed owing to an unexpectedly wet year and the reliance on single-use materials, preventing continuation in a subsequent hot and dry year. Some participants described this series of unfortunate events and decisions as ‘a very bitter pill to swallow’. Still, whether successful or not, the measures experimented and researched served to establish new insights across all learning levels.

4.4.2. PATHWAY 2: COLLABORATIVE NETWORK FORMATION PATHWAY

The process of collaboratively identifying stakeholders begins in several ways, depending on the context, project, and existing relationships among initial participants. The main activities in network formation as initiated by the KLIMAP’s core group (Table 4.1) include framing the challenge, identifying key stakeholders, inviting these relevant stakeholders, establishing agreements on contributions, and assigning roles within the living lab. Roles include coordinators, facilitators, team leaders, and ambassadors for the respective organizations.

KLIMAP, being a continuation of the earlier network Lumbricus, had the opportunity to leverage the existing network and expand it with new organizations. Recognizing the need to broaden and disseminate the project’s knowledge, stakeholders from Lumbricus established KLIMAP with a wider scope. Consequently, various Lumbricus stakeholders joined KLIMAP and invited new organizations. The KLIMAP network numbers 24 partners and is comprised of water-authorities from the sandy soil regions, associated provinces, diverse research universities and institutes, private organizations, farmer’s organizations, and individual farmers. Each stakeholder had specific roles and responsibilities: water-authorities ensured the innovation’s practicality. Farming organizations aligned innovations with farmers’ well-being and sustainable farming practices, while nature organizations aligned innovation with preservation of nature areas. Private organizations provided instruments and innovative business models, whereas research institutes led in knowledge contributions. However, in terms of expertise, not all were continued e.g., ecologists.

KLIMAP enabled stakeholders to understand each other’s working methods, share diverse insights, realize the strength of collaboration, and form deeper connections. One actor shared their amusement at how neighboring water-authorities had different approaches to tackling similar problems and that KLIMAP acted as a platform to connect their knowledge. These connections allowed actors to gain insights into other similar organizations, learn from them, and share new insights with their respective organizations, leading to various new relations and projects. These included smaller collaborations between organizations, connection with similar network projects such as Farms of the Future and Masterplan IJssel Vallei, and the formulation of new projects such as CASTOR, NAT, Waterscapes, and Reshape (Figure 4.5). In the survey, 93% of KLIMAP participants reported higher understanding of other actors’ and organizations’ perspectives, and 100% reported planning to apply insights to future projects or in organizations.

Involving relevant stakeholders, although crucial, can often be very challenging. One of the actors recalled network formation as a particularly time-consuming and

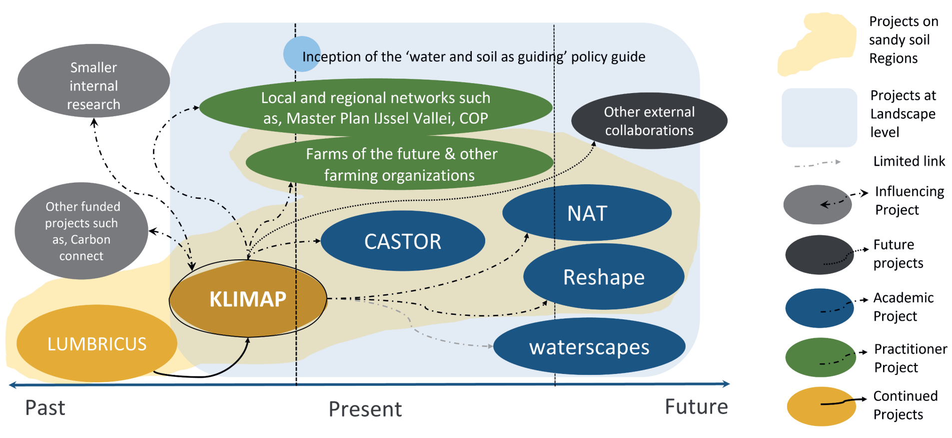


Figure 4.5.: A network of projects associated with KLIMAP.

resource-intensive process, and that *"most organizations agreed to join once a few key organizations committed"*. Another actor noted, *"working within a group of other similar organizations enhances legitimacy and reduces uncertainty in making transformative decisions that would be challenging individually"*.

This highlights the importance of peer influence and building relational social capital to facilitate cooperation and collaboration. In conclusion, an incidental mix between a part of the existing stakeholder network and additional new networks led to improved trust and novel perspectives in KLIMAP. Occurring primarily at the organizational levels, the network formation pathway in KLIMAP focused on building a collaborative network of relevant stakeholders.

4.4.3. Pathway 3: Capacity enhancement pathway

KLIMAP was designed to facilitate and support the practical application of climate-adaptive knowledge and skills development through co-creative workshops and sessions. To guide and assess exploration of development paths, a 'framework', 'evaluation tool', and 'serious game' were developed (Table 4.1).

Decision-makers often find themselves unprepared to implement innovative climate-resilient actions. Innovations face challenges competing with stable regimes, as existing socio-technical systems are stabilized by lock-in, path dependency, and 'entrapment' (Bulkeley et al., 2016). To address this gap, KLIMAP introduces climate-adaptive development pathways, enhancing the decision-making capacity of involved actors. It involves designing landscapes at the systems level with a long-term vision linked with current short-term actions ("KLIMAP", 2024). This approach ensures that decisions taken are flexible and adaptive while ensuring that decision-makers share their interests, values, and visions for the area with all relevant stakeholders early in the process.

Within KLIMAP, a 'roadmap' was developed to provide structure and facilitate the application of development paths in six case studies located at Chaamsche Beek, Vitale Peel, Reusel, Stegeren, North Limburg, and Northern IJssel Vallei. Each case was organized separately with unique goals. Some focused on developing the capacity to apply adaptive pathways in decision-making, others on testing climate-adaptive measures. Various co-creation strategies were employed to achieve these goals, such as maintaining diversity within each working group, followed by moments of feedback to evaluate the usefulness of the workshops and tools such as, 'PrAAT: Practical Adaptation Assessment Tool', serious games, and future visualization were employed. PrAAT was applied to evaluate pathways. The serious game built understanding, awareness of potential unexpected situations, and capacity to make informed decisions to address such scenarios. The simulated game environment presented players with diverse scenarios and choices, highlighting the value of collaboration, forward-thinking, reflection on priorities, and building good relationships. As one actor noted, *"To learn something, we need to go through the same process (practice) several times"*. In the survey, 100% of the participants from KLIMAP reported that they learned from these practical experiences.

However, many actors recalled working in a large consortium as slow and almost ineffective. Nevertheless, they acknowledged that despite the substantial time it takes, co-creation is valuable in addressing climate-related issues comprehensively; as the saying goes, *"Alone you go faster, but together you go further"*. They also remarked that KLIMAP was the first project to develop climate-adaptive pathways for water and land management in Dutch sandy soil context. Developing and implementing multiple methods and tools enhances the procedural knowledge or 'know-how' involved in adaptation pathways among the stakeholders. This learning pathway combines both content and capacity learning, improving the readiness level of individuals and teams for applying climate-adaptative pathways.

4.4.4. Pathway 4: Knowledge and tools adaptation and contextualization pathway

A wide range of activities was organized within KLIMAP to enable actors to resituate and apply knowledge and tools in diverse contexts through cross-connecting platforms (Sole & Edmondson, 2002). These included multiple communities of practice (CoPs), co-creative workshops, learning sessions, and joint analysis (Table 4.1). These activities promoted refined knowledge, improved capacity for knowledge application, and fostered newer connections.

To refine the concepts and tools, insights gained through KLIMAP—such as understanding development pathways, scenario analysis, identifying area-specific climate-adaptive measures, applying various frameworks and tools, and gaining a comprehensive perspective—were adapted to different contexts both within and beyond the project. For instance, a seven-step roadmap was developed to guide the application of development pathways (Figure 4.6). Initially, these steps were expected to follow a linear sequence, but as the roadmap was applied in diverse contexts, stakeholders realized that the steps need not be sequential nor start with step 1.

KLIMAP also held learning sessions open to all stakeholders, focused on unique topics that did not arise during other collaborative activities, e.g., regulating drainage systems, upscaling measures, addressing power dynamics in decision-making, and

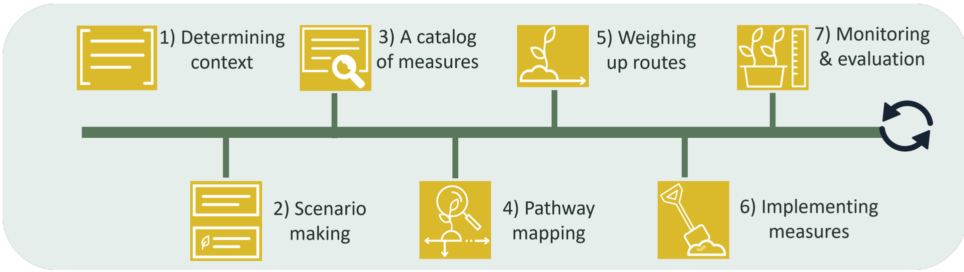


Figure 4.6.: KLIMAP roadmap (“KLIMAP”, 2024)

acknowledging emotions related to climate change issues. These sessions aimed to extract knowledge and make it explicit within the network, allowing it to be reintegrated into their ongoing work. Peer-to-peer interactions and feedback, collected through open participation or online tools like Mentimeter, enhanced participants' understanding and strengthened their networks. The unique nature of these topics provided new insights and experiences that participants might not have had easy access to otherwise. Notably, 100% of survey respondents from KLIMAP found these learning sessions a valuable co-creation activity.

Regular CoP meetings created opportunities to brainstorm, co-create solutions, share results, and learn from one another. These interactions improved stakeholders' abilities to adapt their knowledge and tools to diverse contexts. The CoP invited additional external actors working on similar climate adaptation projects in the region; thus, new connections were fostered while strengthening learning and capacity-building. Ultimately, this learning pathway highlights how diverse activities within the cross-connecting platforms empower actors to aptly reapply their knowledge, skills, and network perspectives in diverse contexts. This contributed to content, capacity, and network learning at all levels.

4.4.5. Pathway 5: Innovation dissemination and upscaling pathway

KLIMAP organized various activities to support knowledge dissemination via mass media and networks. Knowledge was scaled up through advocacy in interpersonal communication channels. Methods included storytelling and blog writing on social media platforms, interviews in mainstream media channels, sharing results in impactful magazines and the project website, and advocacy in public organizations to impact the institutional setting (Table 4.1).

From the outset, KLIMAP shared its vision and preliminary results on climate adaptation through its website and mass media outlets like radio, newspapers, magazines, and social media, to invite external engagement. The knowledge developed during KLIMAP was available through its website, openly or on-request. Social media platforms were used to share stories and blogs on ongoing activities that were eventually picked up by the media, gaining more attention. KLIMAP employed various communication methods to reach a diverse audience, including sharing reports, visual maps, short videos, and flyers. This multifaceted approach was designed to engage a wide range of potential collaborators and disseminate the knowledge created during the project. Consequently, many collaborations emerged from KLIMAP's communication efforts. For instance, a research team in Minnesota approached KLIMAP regarding the experiment on 'corn with permanent under-crop'. Further, KLIMAP's serious game was used in another context of Delta programs by external users and in universities for teaching purposes.

Another method of knowledge dissemination was inviting external stakeholders (Mol & Birkinshaw, 2014) to events such as CoPs and symposiums. KLIMAP consistently shared project insights across other networks, thereby influencing their decision-making. For instance, the Masterplan IJssel Vallei, which had overlapping stakeholders with KLIMAP, employed the development pathways concept in its decision-making process. A dike reinforcement plan wasn't carried out to prevent future lock-in situations. The survey of external participants showed that 50% of participants understood more about climate adaptation, 91% found knowledge from the symposium applicable to other projects and situations, and 100% planned to apply the knowledge in their organization.

For knowledge upscaling, KLIMAP made numerous contributions to Deltafacts, a concise and factual summary of practical knowledge in the field of water management, which is primarily consulted by policy officers, managers, and experts in the Netherlands (Deltafacts, 2023, 2024). Throughout the project, KLIMAP leveraged interpersonal connections to try and establish their innovations within diverse local settings and institutions, as one actor noted, *"we are ambassadors of climate adaptation measures for our respective organizations"*. Another actor highlighted, *"we all have a role in maintaining and continuing the project's outcomes after its completion"*.

KLIMAP stakeholders shared their flexible, development-focused philosophy with administrators and board members from municipalities, water-authorities, provinces, nature and agriculture organizations, and other external networks, creating possibilities for continued collaboration ("KLIMAP", 2024). Further, KLIMAP identified revenue models tailored to specific sub-areas (high grounds, flanks, and stream valleys) and proposed ideas for new subsidies.

KLIMAP's efforts coincided with numerous external organizational changes, e.g., many water-authorities were attempting to incorporate sustainable choices into their decision-making. At the same time, the Dutch Ministry of Water and Infrastructure introduced a "water and soil guiding" policy document. This policy document aims to restore natural water and soil systems, emphasizing the need to enhance resilience and robustness. By designing land-use functions to promote cohesion and sustainability, this approach is critical in shaping the country's resilience to climate change and biodiversity preservation (de Rooij et al., 2023). Some organizations involved with KLIMAP were involved in the phases leading up to the formulation of this policy document. Over the years, numerous living labs and co-creative projects have focused on climate-resilient water and land systems in the Netherlands. This underscores the importance of viewing water and soil management holistically. While all these forces seem to come together, a question remains regarding the extent to which the relevant bodies will use the knowledge created during KLIMAP after the project's conclusion. This pathway explains how KLIMAP took intentional actions to disseminate and upscale knowledge, reaching wider interest groups. Simultaneously, it explains the network aspect (societal engagement and policy influence) and content aspect (knowledge transfer and feedback) primarily at organizational level.

4.4.6. PATHWAY 6: CO-CREATION FACILITATION PATHWAY

In a living lab approach, the mindset of collaboration and willingness to learn are prerequisites. Ensuring clear and neutral communication is continuous and requires mindful effort throughout the project. Besides having shared project goals, open communication channels are required for clear and neutral communication. The major activities to facilitate co-creation in KLIMAP included designing effective communication strategies, promoting open dialogues and active listening, facilitating group discussions, and providing additional support training (Table 4.1).

KLIMAP devised a communication structure resting on transparency through a web portal to share updates. KLIMAP utilized SharePoint as a platform for sharing information, making all resources, results, and reports accessible to all members. The intermediate products and links to relevant websites were placed in a central accessible location. In transdisciplinary work, where diverse disciplines and sectors interact, it's important to use plain language. Terms and concepts should be explained clearly by providing context, encouraging questions, and facilitating mutual understanding. For instance, in one of the case studies in KLIMAP, not all participants understood the hydrological concepts. Some stakeholders felt out of place and refrained from participating in discussions for fear of appearing ignorant. Consequently, additional training and supportive resources were provided, ensuring all participants were on the same page. Follow-up measures helped fill any remaining gaps. An actor reflected on the value provided by co-creative projects as, *"“We need to take into account the needs and wants of all stakeholders. A lot of times, we think we have an idea of what is needed, but that's a big assumption, and our idea can be very different from reality. Co-creation will not be straightforward like other research where you'd make propositions, execute, and show results; it is a messy process. But we get to know the ‘real’ reality, not ‘assumed’ reality”.*

Living labs need to strike a delicate balance when addressing sensitive topics to minimize conflict and miscommunication. For example, KLIMAP aimed to develop a strategic understanding of decision-making and to foster system-level conversations about innovation measures. Since individual lands were closely tied to owners' identities, moving the discussion from a parcel-level to a regional-level was important. Thus, strategies and measures were presented based on the regional water-table, categorizing land-parcel into sub-areas: high ground, brook valley (low ground), and flank (slope area from high to low ground). Accordingly, relevant strategies and measures for each sub-area were discussed. This learning pathway deals with enabling factors for co-creation, requiring projects to intentionally select or develop strategies that allow all the actors to contribute equally, deepen their understanding of various topics from diverse actors' perspectives, and develop the capacity to apply these concepts in practice.

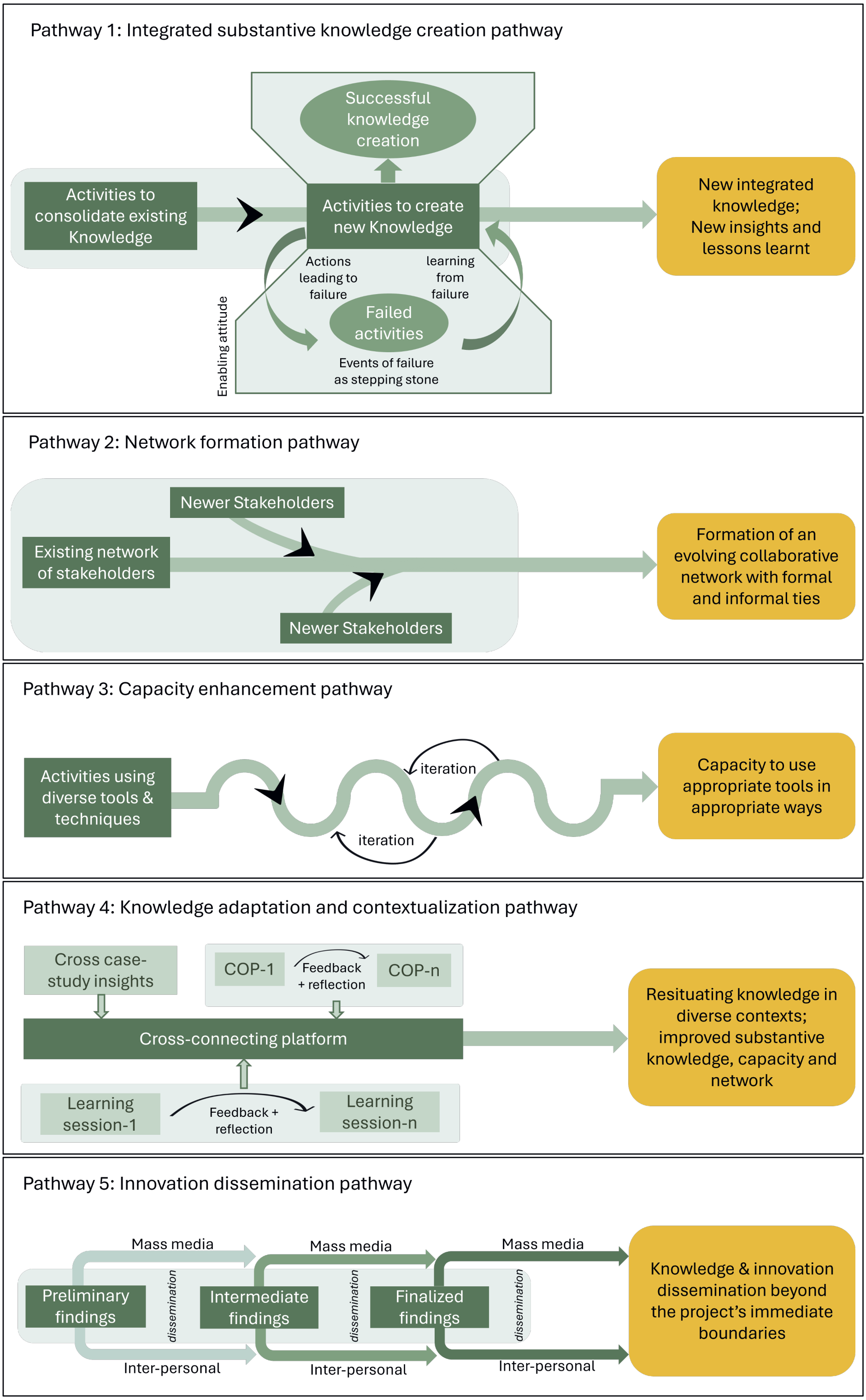
4.4.7. PATHWAY 7: REFLECTIVE LEARNING PATHWAY

KLIMAP encouraged reflexivity among the stakeholders and the project itself. The activities included continuous feedback and discussions, recording experiences, and (informal) participatory monitoring (Table 4.1). KLIMAP engaged in several reflective moments, which eventually led to development of diverse interventions. One notable instance involved the use of causal loop diagrams. To let actors realize the difference between decision-making in "isolated sectoral silos" versus "interdisciplinary groups", sector-specific groups were formed and tasked with creating causal loop diagrams of water flow in the area. The diagrams produced by each group were strikingly different, highlighting the diversity of perspectives and sparking meaningful conversations on how and why the flows were perceived differently. These interventions deepened actors' understanding of each other's priorities and perceptions from the standpoint of their organizational roles. One participant noted that this exchange among diverse stakeholders made the KLIMAP experience uniquely valuable.

Another example of reflective intervention occurred when KLIMAP actors reflected on the need for better communication across different working groups. Many actors chose to focus primarily on their individual responsibilities and thematic working groups, only cross-connecting with the rest at a later stage. Reflecting on the lack of strategies to connect working groups, coordinators made additional efforts to improve connections midway through the project. This strategic facilitation to cross-connect different thematic work led to some successful collaborations, even though some actors still felt these efforts should have started earlier for better integration. The core concept applied in KLIMAP, i.e., development pathways, has a reflective element to it as well. Designing these pathways requires actors to think forward to a future situation and then reflect on the appropriate short-term interventions. Thus, self-reflection, collective reflection, and feedback and discussions were central to KLIMAP.

KLIMAP started with the goal of developing system-wide measures for sustainable water and landscapes. However, it was soon realized that a complete set of measures at the landscape level requires much greater political and social support. While this was initially frustrating to the stakeholders, they realized their role was to initiate change by disseminating their knowledge and engaging with relevant organizations so that ideas could take root. Thus, KLIMAP did not follow the familiar forms of monitoring and evaluation. An actor noted that recording learning and reflecting collectively during the project would have been valuable, as people tend to forget what they learned over time.

However, informal and participatory monitoring and evaluation were selected so that actors learned together to tackle challenges and jointly develop solutions. Reflecting on their experience allowed actors to reflect on their activities and recognize the resulting incidental learning (van Mierlo et al., 2020). The capacity to (collectively) reflect, rectify, and make recommendations can greatly benefit individuals and organizations, enhancing their current and future learning.



Pathway 1: Integrated substantive knowledge creation pathway
Successful knowledge creation
Activities to consolidate existing Knowledge
Activities to create new Knowledge
New integrated knowledge; New insights and lessons learnt
Actions leading to failure
learning from failure
Failed activities
Events of failure as stepping stone
Enabling attitude
Pathway 2: Network formation pathway
Newer Stakeholders
Existing network of stakeholders
Newer Stakeholders
Formation of an evolving collaborative network with formal and informal ties
Pathway 3: Capacity enhancement pathway
Activities using diverse tools & techniques
iteration
iteration
Capacity to use appropriate tools in appropriate ways
Pathway 4: Knowledge adaptation and contextualization pathway
Cross case-study insights
COP-1
Feedback + reflection
COP-n
Cross-connecting platform
Learning session-1
Feedback + reflection
Learning session-n
Resituating knowledge in diverse contexts; improved substantive knowledge, capacity and network
Pathway 5: Innovation dissemination pathway
Mass media
Mass media
Mass media
Preliminary findings
dissemination
Intermediate findings
dissemination
Finalized findings
dissemination
Inter-personal
Inter-personal
Inter-personal
Knowledge & innovation dissemination beyond the project's immediate boundaries

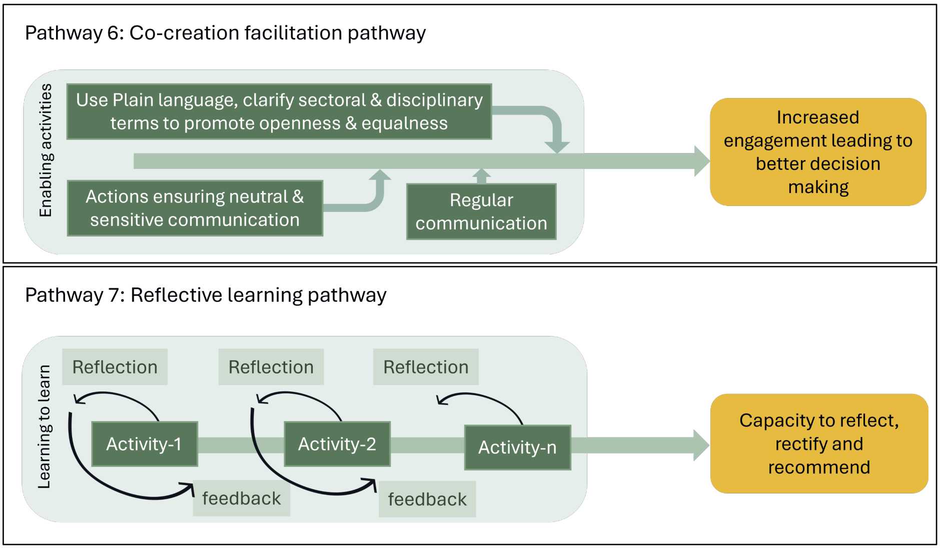


Figure 4.7.: Illustration of summary of the learning pathways mapped in KLIMAP

4.5. Discussion

This research developed learning pathways based on the KLIMAP project by applying the learning framework of Bhatta et al. (2024). The ex-post analysis of KLIMAP has affirmed the existence of seven learning pathways, primarily determined by the learning type (Figure 4.7). These pathways highlight how KILMAP's co-creation activities influenced knowledge acquisition, capacity building, and perspective understanding, among other factors, leading to diverse outcomes. Often, strategies change when an innovative project is underway, and the results also only become visible after some time has elapsed (van Mierlo et al., 2010). However, the learning pathways support capturing values that extend beyond immediate results, contributing to a broader understanding of the topic, increasing collaborative efforts, and scaling up innovations.

The first pathway, which deals with leveraging existing knowledge and integrating it with new knowledge developed during the project, also accepts that moments of failures are likely in innovative projects owing to their uncertain and experimental nature (D'Este et al., 2016; Jenson et al., 2016). Although failure is never intentional, it is intertwined with the innovation process to the extent that its probability increases with the intensity of innovation (Kamoto, 2017; Rhaiem & Amara, 2021). Counterintuitively, failure provides valuable lessons. Research shows that knowledge gained from failure depreciates more slowly than from success (D'Este et al., 2016; Madsen & Desai, 2010). Factors like a shared vision, a sense of belonging, and high-quality relationships can positively influence learning from failure, generating new insights, and enhancing reflection on past decisions.

Similarly, the second pathway identifies the stakeholders' role in bringing legitimacy and resources to address the issues (Chen & Musango, 2022). When establishing a living lab, integrating an existing network, or a part thereof, can be advantageous if it aligns well with the lab's goals (Willem & Lucidarme, 2014). Existing networks leverage pre-established trust and accelerate the collaboration process, while new networks bring new resources, perspectives, and heterogeneity (Soda et al., 2021). Thus, it is beneficial to adopt ongoing collaborations as social capital while enriching them with perspectives from new stakeholder networks. However, which part of an existing network is continued can depend on the availability of existing partners and the interests of personnel driving the project.

More generally, to enable transdisciplinarity, living labs can choose to maintain a unified knowledge base, common vocabulary, and consistent interpretations to ensure effective communication regardless of participants' background or expertise, as terms and concepts common in one field might be new to another (Hunter, 2016; Smol, 2018). Likewise, the pathway on knowledge diffusion and upscaling that aims for institutional and policy changes for system-wide sustainability (Moore et al., 2015; Scholl et al., 2022; Sengers et al., 2019) determines the fit (or misfit) between diffusing practices and adopters regarding technical, cultural, and political elements (Ansari et al., 2010). While KLIMAP carried out several activities to disseminate and scale up the knowledge produced, its long-term impact and potential to drive institutional and policy changes remain unclear. The proposed revenue models are still in the early exploratory stages, meaning that start-ups rely on external funding or subsidies to compete in an established market. This highlights the need for top-down intervention to create viable business opportunities. However, it is unclear whether relevant organizations will adopt these policy recommendations. Such impacts can only come to light over time and cannot be addressed in the short-term (Watermeyer, 2014). Nevertheless, CoPs are still planned even after the project's completion by other partners in the network (Figure 4.5).

These learning pathways align closely with the core principles of living labs. Pathway 1 advances learning through real-life exploration and experimentation. Pathway 2 augments early and continuous engagement with all relevant stakeholders within the quadruple helix framework. Pathways 3 and 4 focus on iterative learning processes, emphasizing inclusivity, openness, and transparency. Pathway 5 stresses the need for value co-creation to enable upscaling. Finally, pathways 6 and 7 adopt a reflective approach, centering on understanding stakeholders' needs, motivations, expectations, and mindsets.

4.6. CONCLUDING REMARKS

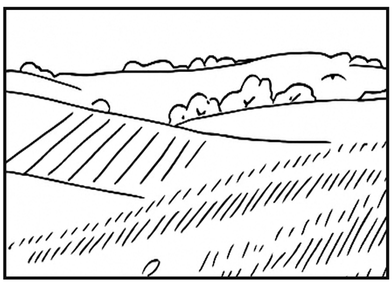
This paper examines how living labs can serve as effective strategies for sustainable land and water management and offers insights into how emphasizing learning in co-creation activities can contribute to a project's overall success. A sequence of learning activities leading to their respective outcomes was systematically documented through 'learning pathways', in alignment with the 'living lab learning framework'.

The paper demonstrates how learning pathways can be used to reflect on and leverage the knowledge gained from a project, enabling actors to better understand the outcomes of their collaborative efforts, identify valuable lessons, and apply these insights to future initiatives. It retrospectively collects learning evidence in the KLIMAP case study to demonstrate how structured learning pathways can reveal the deeper, often overlooked effects of co-creation processes. Seven distinct pathways were identified, focusing on: 1) harnessing collective, integrated knowledge, 2) building collaborative networks, 3) enhancing stakeholder capacity, 4) adapting and contextualizing knowledge, 5) innovation diffusion, 6) facilitating co-creation, and 7) reflecting and learning. Each pathway highlights learning activities—categorizing learning type, process, and involved entities—and their resulting outcomes. These pathways document the evolution of knowledge and skills, demonstrate the effectiveness of activities and interventions, offer enhanced accountability, and provide valuable insights for improving future project design and implementation.

A limitation of our study lies in the generalizability of our case study results. While the learning framework is grounded in a systematized theoretical system, making it applicable to various empirical studies, the learning pathways were developed within a single case study in the context of Dutch governance, where sustainable land and water are a priority (Pot, 2024). Thus, it is unclear how reflective KLIMAP is of other complex, real-world challenges in different regions and governance systems worldwide. Pathways for other living labs can be different based on their design, socio-political position, and operationalization. More case studies on living labs in other regions are, therefore, recommended. Since the learning pathways in this study were developed retrospectively based on the stakeholders' recollections, certain components of the living lab learning framework—such as the diverse levels of learning—weren't fully captured. Accordingly, future research should focus on refining and expanding these pathways, not only in ex-post project evaluations but also during the design phase of projects and incorporating multiple case studies. Further, the paper approaches learning pathways from the primary perspective of learning type; the implication of adopting learning process or level as the primary perspective is unknown and could offer a fruitful starting point for future research. While this paper highlights the significance of learning in amplifying the broader impact of living labs, further research is also needed to deepen the understanding of living labs within policy contexts. Living labs can offer valuable evidence for policymaking, not only through the co-design and co-creation of innovative solutions and substantive knowledge but also through knowledge dissemination, inclusive network building, adaptability, transparency, and increased credibility. Therefore, additional research is necessary to determine how living labs can best support the inception, implementation, execution, and monitoring of policies, particularly those focused on sustainable land and water management.

5

INFLUENCE OF LIVING LABS IN THE POLICY LANDSCAPE



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ABSTRACT

Living labs have emerged as policy tools, research infrastructures, and governance mechanisms within the contemporary policy landscape. However, understanding how they are designed and positioned within policymaking processes, and the conditions that allow them to influence policy is still limited. Accordingly, this paper maps the role of living labs across different policy phases and identifies factors enabling their policy influence. First, a review of living lab literature related to policymaking processes is conducted, revealing that most studies are concentrated in the pre-policy, policy delivery, and post-policy support phases. Second, four living lab cases in the Netherlands within the field of climate-adaptive water management are explored to understand their positioning within the policymaking phases, policy influence, and the factors enabling such influence. The analysis identifies five factors enabling the policy influence of living labs, namely: (i) strong stakeholder engagement and commitment, (ii) emphasis on structured learning, (iii) alignment with both societal needs and broader policy agendas, (iv) supportive institutional and political environments, and (v) generation of credible, high-quality evidence. The study offers insights into the current positioning of living labs within the policy phases and highlights the factors enabling their policy influence.

5.1. INTRODUCTION

Addressing complex societal challenges, such as sustainable water and land use, calls for innovations in public policy approaches that draw on knowledge from the science-policy-society interface (Eberle et al., 2021). Bridging this interface to enable policy innovation often requires boundary-spanning processes, such as co-creating knowledge (Schot & Steinmueller, 2018). Innovation in public policy (whether at the multi-national, national, or local level) necessitates understanding the nature and implications of political discourse, and the broader dynamics of new knowledge creation, organizational evolution, and emerging relations in a given context (Aggeri, 1999). As a result, public policy processes have become more dynamic and interactive, fostering collective innovation through collaboration amongst diverse stakeholders to develop strategies for policy design that deal better with complexity (Aggeri, 1999). Such collaboration is particularly sought in liberal democracies where citizens and policymakers tend to favor less coercive instruments that uphold a "high level of autonomy and responsibility" aligned with their values (Howlett et al., 2023). Empirical evidence further highlights that collaborative governance and cross-sectoral collaboration, particularly co-creation activities outside public organizations alone, significantly enhance the potential for policy innovation (Frantzeskaki et al., 2025).

Living labs have emerged as a policy tool, research infrastructure, and governance mechanism (Nesti, 2017; Polman, 2025; Schliwa & McCormick, 2016; Veeckman & Temmerman, 2021) in the policy landscape. Living labs are user-centric, co-creative approaches that facilitate multiple stakeholders to innovate in real-world settings (Bhatta et al., 2024; Leminen et al., 2012). In the past, these labs referred to experimental environments where technologies were developed or refined with end-users in real-life settings, primarily within private firms and industrial contexts (Bhatta et al., 2024; Nesti, 2017). Over time, their scope has broadened across both application domains and geographical settings (Bhatta et al., 2024), giving rise to urban living labs (Steen & Van Bueren, 2017), campus living labs (Stuckrath et al., 2025), and other variants. They are applied in diverse contexts that require (i) transdisciplinary and trans-sectoral collaboration and learning (Bhatta et al., 2025b), (ii) interactive and inclusive citizen-engagement (Brons et al., 2022), (iii) open and user-centric (citizen-centric) innovations (Schuurman, 2015; Veeckman & Temmerman, 2021), (iv) addressing complex societal (wicked) challenges, and (v) promoting long-term societal transformation (Backhaus et al., 2023), making them relevant within the policy landscape (Trei et al., 2021).

Although living labs are gaining global traction, their application within the policy landscape is particularly prominent in Europe (Mahmoud & Morello, 2021; Nguyen et al., 2022). EU policies strongly encourage collaborative and innovation-oriented approaches that strengthen democratic processes, such as living labs (Lupp, Huang, et al., 2021). The European Union (EU)'s major research and innovation (R&I) frameworks, such as Horizon 2020 (2014-2020), Horizon Europe (2021-2027), and the forthcoming Next Framework Programme-FP10 (2028-2034), have recognized and integrated living labs into their funding and implementation strategies. Under the Horizon 2020 program, over 750 projects incorporated living labs (ENoLL, 2025), a trend that continues under Horizon Europe, where living labs are included as one of the technology infrastructure concepts in public policy (European Commission, 2024). In Horizon Europe, the European Commission has further reinforced the role of living labs through its five EU Missions to address some of the greatest challenges facing our society. These missions incorporate the living lab approach, among other methodologies, to advance key EU policy priorities such as the "European Green Deal", "Europe's Beating Cancer Plan", "Next Generation EU", "EU Industrial Strategy", and "A Europe fit for the Digital Age", amongst others ("Horizon Europe", 2024). Set to start in 2028, FP10 already has several position papers from member states, regional authorities, and European organizations, calling for a robust, agile, and future-proof program ("Next Framework Programme (FP10)", 2025). The European Network of Living Labs (ENoLL), a globally focused living lab network organization, has played a pivotal role in positioning living labs within the public policy landscape. 74 ENoLL-accredited living labs cite 'policymaking' as their field of expertise, and 20 specify 'policies' as their areas of work ("ENoLL Members Catalouge", 2025).

The application of living labs in the policy landscape is multifaceted (Gascó, 2017; Nguyen et al., 2022). First, they function as open innovation intermediaries that drive public sector innovation by integrating diverse stakeholders, i.e., citizens, policymakers (governmental agencies), researchers, and businesses, in actively shaping policy decisions (Gascó, 2017). Thus, as boundary-spanning instruments, they can overcome the obstacle of having scarce actors in the policy process and make innovations in living labs open and user-centric. Second, they engage citizens and end-users to enable the iterative dialogues required to support policy actions (Leutert, 2021). Citizen engagement enhances policy's legitimacy by ensuring that decisions are inclusive, participatory, and representative. Such living labs may also conduct activities to promote bottom-up innovations in the public sector, fostering more inclusive and adaptive policymaking (Hillgren, 2013). Third, they offer valuable contextual insights and produce evidence through real-world experiments to support evidence-based policymaking (Mahmoud & Morello, 2021; Salvia et al., 2023). Evidence addresses the growing demand for data-driven policymaking and brings credibility to the policy measures. Consequently, living labs are applied as policy experiments where innovative solutions can be tested, refined, and scaled (Commission, 2025).

Despite the increasing application of the living lab approach within public policy landscapes, their influence on policymaking and ancillary processes is neither automatic nor guaranteed (Willems et al., 2023). Understanding of how living labs are applied within the public policy landscape and the conditions that allow them to influence policy is still limited. Therefore, this study aims to map how living labs are positioned within policy processes and to identify the factors enabling living labs' policy influence. We undertake this aim through literature study and case study analysis. First, we sketch the public policy landscape, then we conduct a literature review to identify the specific phases of policymaking in which living labs are operationally involved. Next, we analyze four living lab cases in the Netherlands that address issues related to water and land management to explore their policy influence and assess the factors leading to these influences.

The paper is structured as follows: Following the introduction and description of the public policy landscape, we explain the research methods and introduce the living labs case study. In the results section, we analyze how the living lab literature is positioned across public policymaking phases and investigate the living lab case studies to determine their policy influence and the factors leading to this influence. Finally, we conclude with a summary of key insights and future recommendations.

5.2. PUBLIC POLICY LANDSCAPE

Ideally, policymaking is an orderly and rational activity, but, in reality, it is neither rational nor linear (Enserink et al., 2022). While often depicted as a neat cycle of policy-related activities (Knill & Tosun, 2008), research has revealed that policymaking seems to have no predefined or universal policymaking procedure; rather, decision-making unfolds through a series of proactive and reactive actions where policymakers may act autonomously or be directed by institutional mandates or political pressures (Anghel & Jones, 2022). Several early empirical studies offered insights into the complexities of decision-making and policymaking. Simon (1955, 1991) found that while decision-makers are intendedly rational, they are bound by limited or inadequate information and constraints, and therefore exhibit bounded rationality in decision-making. Wildavsky (1979) found that public decision-makers prefer a process where changes are made in small steps rather than through large shifts. Lindblom (1959) coined the term 'muddling through' to describe the incremental and incomprehensible reality of the policymaking process. These insights led to theoretical approaches to policymaking, such as the multiple streams framework by Kingdon (2003) which suggests policy change happens when three streams (problems, policies, and politics) align, creating a "policy window" for action. The punctuated equilibrium theory by Baumgartner and Jones (2009) argues that policymaking is a slow and incremental process occurring in long periods of stability (equilibrium) but can shift dramatically to diffuse policy innovation in case of crises or major political changes. The advocacy coalition framework by Sabatier and Jenkins-Smith (1999) argues that policy changes when different groups with shared beliefs form coalitions, that actively seek to influence policies over time. The Institutional Analysis and Development (IAD) framework, by Ostrom et al. (1994), provides a structured approach to understanding how actors interact within a policy landscape, that is under specific rules, norms, and governance structures, and how institutional arrangements can shape behavior and outcomes through incentives and constraints. While these theories and frameworks have their strengths and limitations, they have been applied independently and in integrated forms to analyze decision-making across diverse policy landscapes (Banha et al., 2022).

Public policy is nested within complex and dynamic policy landscapes, where policy goals and the means to achieve them vary in their level of abstraction and application (Rittel & Webber, 1973). In modern democratic systems, such as the EU, policymaking unfolds across multilevel structures of institutions and agencies, functioning at various levels, from national governments to local administrations (Benz, 2016; Hooghe & Marks, 2001). In recent times, policymaking authority has dispersed from the central government upwards to the supranational level (e.g., EU), downwards to the subnational level (e.g., provincial and local governments), and sideways (horizontally) to private and societal networks (Hooghe & Marks, 2001). Increasingly, local governments, such as cities and municipalities, use their autonomy to design and implement policies that reflect community-specific needs, often leveraging collaborative approaches to innovate in addressing policy (Kourtit et al., 2011; Masuda et al., 2022). Engaging a diverse network of state and non-state actors in policymaking fosters social capital and shared ownership, harnesses collective knowledge, and enhances civil engagement, leading to more effective and widely accepted policy outcomes (Agranoff & McGuire, 2003). Integrating collaboration, experimentation, and innovation into policymaking occurs through a range of strategic activities across diverse phases, as presented in Table 5.1. These activities include participatory needs assessments, knowledge and evidence building, co-creating with the networks of actors or coalition forming and so on. The strategic activities undertaken to support policy development each contribute to different phases, namely (i) pre-policy, (ii) policy design, (iii) policy delivery, (iv) evaluation, and (v) post-policy support. Here, pre-policy involves agenda-setting and the groundwork for new policies, policy design involves activities related to policy formulation, policy delivery focuses on implementation activities, evaluation includes monitoring and appraisal activities, and post-policy support involves activities related to adapting and adjusting policies.

Table 5.1.: Activities in policymaking process through a collaborative and experimental lens

Phases	Activities
Pre-policy	• Research and analysis: pilot experiment to generate evidence, gathering representative input (engaging community members, researchers) to inform and influence new policy priorities (Nesti, 2017; Polluveer, 2024), for example, by collecting local data through citizen science, interviews, storytelling (Wehn et al., 2021), narratives (Bontje & Slinger, 2017), or digital tools, and integrating data-driven participatory evidence (Kohlgrüber et al., 2021) • Building trust, collaboration, identity, aligning values, and capacity for social action (Swanson & Bhadwal, 2009) • Participatory needs assessment: clarify value and arguments (Mayer et al., 2004), explore, understand and define problems collaboratively (Ansell et al., 2017) • Anticipate areas for improvement or development (Schot & Steinmueller, 2018) • Agenda-setting and making a case for why an issue deserves public attention

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Table 5.1 – continued from previous page

Phases	Activities
Policy Design and planning: *The deliberate attempt to define policy goals and consciously connect them to policy instruments intended to reach those goals (Howlett, 2011)*	• Design & recommend: Integrate strategic foresight and collaborative approaches into the design of new initiatives by, – Engaging multi-stakeholder committees to "co-develop" policy proposals through co-learning and cross-fertilization of ideas to design policies (Schot & Steinmueller, 2018), using collaborative dialogue, structured discussions, experimentation and evaluation (Osler & Starkey, 2006; Ricart et al., 2019) – Co-design inclusive policies that directly respond to the needs of end-users, integrating data-driven and participatory evidence (JRC, 2023; Kohlgrüber et al., 2021) • Identifying shared responsibilities and resources between government and non-government entities, pooling resources (government subsidies, private funds, citizen's insights) (Arku & Oosterbaan, 2015) • Democratization: localized analysis helps tailor national or supranational policy frameworks to better fit diverse contexts and communities • Policy innovation through invention (novelty) or experimentation (Goyal & Howlett, 2024; Jordan & Huitema, 2014)
Policy delivery *The process of putting a policy into effect, involving implementation, testing and refinement through various tools and interventions*	• Co-creation: Bringing different actors (breaking silos) to design policy interventions tailored to their environment supporting existing policy or policy agenda; continuously adjusting the interventions based on real-time feedback and results, that is crucial for addressing complex, evolving problems (Santos & Coad, 2023) – Integrating data-driven and participatory evidence (Kohlgrüber et al., 2021) for ex-ante evaluation to ensure that the intervention is relevant (Santos & Coad, 2023) – Pilot interventions for policy implementation/ Policy experiments: testing the effects of policy interventions in a real-world setting and measuring the impact of new and innovative policy before full-scale implementation (Bravo-Biosca, 2020; Commission, 2025); Experimentation can take the form of pilot programs, randomized controlled trials, prototyping, or regulatory sandbox, to test initiatives (McFadgen & Huitema, 2018; Nair & Vreugdenhil, 2020; Vreugdenhil et al., 2010) • Advocate innovative interventions to put a certain policy into effect, Managing resources and capacities • Adaptive: Modifying policies and interventions based on new challenges or emerging insights during execution

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Table 5.1 – continued from previous page

Phases	Activities
Evaluation	• Developing and promoting the use of analytical tools to support policy development, monitoring and quantitative impact evaluation (JRC, 2023) by including models, field trials, impact evaluation, composite indicators and scoreboards, etc. • Participatory and reflexive Monitoring: Involving relevant actors in tracking policy implementation progress and effectiveness (Onyango, 2018), Feedback Mechanisms: Gathering direct input on the effectiveness of interventions. • ex-post evaluation aiming to account for the achievement of expected goals, the effectiveness of interventions and the sustainability of impacts (Santos & Coad, 2023)
Post-policy support: *Ongoing policy processes of adjustment & adaptation of interventions, informing future policies, and further feedback to the pre-policy phase*	• Adapting and updating policies & interventions to deal with new challenges or to include new perspectives/ contexts • Policy coherency assessing consistency between policies, synergies and trade-offs among different policy instruments and domains (Cairney & Toomey, 2024) • Policy integration (Cairney & Toomey, 2024): promote collaboration among different policy domains and stakeholders) through a holistic approach • Policy transfer: diffusion of policy ideas and practices across different jurisdictions or contexts (Willems et al., 2023) • Policy learning; drawing lessons from past policy experiences and using them to inform future policy decisions and capacity building (JRC, 2023); Institutionalizing learning processes for long-term policy refinement • Knowledge diffusion and learning, upscaling and replicating (Polluveer, 2024), exploring opportunities and lobbying to upper-tier government (Arku & Oosterbaan, 2015) • Institutionalization: embedding the interventions into formal structures and the practice of governance
Overarching	• Provision of platform or generative space (tools & principles) to host collaborative dialogue, experiment interventions, and co-learning (Ansell et al., 2017; Zurbriggen & Lago, 2024) • Create a strong science-policy-society network; Strengthen innovation ecosystem (Polluveer, 2024); Promote innovation in policy areas (JRC, 2023; Nesti, 2017) • Strengthening partnerships and networks for sustained long-term engagement, helping to build trust, transparency, & a sense of ownership of collaborative actions (Ansell et al., 2017), Embedding co-creative approaches (e.g., LLs) structurally into policy processes

The policymaking phases are not viewed as sequential phases in a neat policy cycle, as this is insufficiently reflective of the dynamic, non-linear and even iterative nature of actual policy processes. Instead, they function as an exploratory guide in understanding policymaking through activities rather than a framework with rigid phase boundaries. Also, some activities may span more than one phase based on their intention and purpose, highlighting their transitional and overlapping roles. Accordingly, in an evolving policy landscape, living labs are viewed as instruments that can potentially influence the policymaking phases through various activities Table 5.1. They seem suitably positioned for bridging the science-policy-society interface, potentially leading to more dynamic, adaptive, research and innovation-oriented, and citizen-driven policy processes, particularly at the sub-national level (cities, local or regional level), where their impact is more immediate and tangible.

5.3. RESEARCH DESIGN

The methodological approach draws on the insights of how the strategic activities undertaken in living labs align with different phases of policymaking (Section 5.2). First, a literature review was conducted to examine the policy-related contributions reported by existing living lab research in terms of phases and activities. Second, four living labs in the Netherlands were investigated to understand how they contributed to policymaking. These case studies were selected to gain an empirical understanding of how living labs contribute to the water policy landscape. Finally, the findings are synthesized to derive an understanding of which factors help living labs influence policy.

5.3.1. LITERATURE REVIEW

To understand how living lab approaches are positioned in policymaking, we conducted a literature search on Scopus and Web of Science (WOS). First, the search keywords "living lab*" AND (“policy landscape” OR “policy*making” OR “policy design” OR “policy research” OR “evidence-based” OR “policy influence” OR “policy agenda” OR “policy measures” OR “policy options” OR “policy alternatives”, “policy formulation”, “policy adoption” OR “policy decision” OR “policy implement*” OR “policy evaluation” OR “policy monitoring” OR “policy support” OR “policy brief” OR “policy document” OR “policy outcome” OR “policy learning” OR “policy integration” OR “policy innovation”) were used for the title, abstract, and keywords, yielding 97 papers. The search covered publications up to March 2025 and was limited to “English” language. A broader search using "living lab*" AND “policy”, in the title, abstract, and keywords, returned 504 papers, many of which used the term policy loosely or incidentally. Thus, to focus explicitly on work linking living labs to policy, we restricted the search to the title field only, yielding 14 papers. Combining all results yielded 111 papers, of which six were repeated, resulting in 105 unique papers. After screening, 46 were found to be unfit for this analysis (see Appendix D, Supplementary material for chapter 5 for reasons for exclusion). The remaining 59 papers were analyzed and categorized according to their position within the policy process, along with the rationale for assigning them to a specific policy phase Appendix D. The analysis was conducted by the first author and independently reviewed by at least one other author to ensure reliability.

5.3.2. CASE STUDY ANALYSIS

For centuries, the Netherlands has actively shaped its land and water system to meet its needs, most notably through polder drainage, land reclamation, and an extensive network of dikes (Niesten & Frambach, 2023; Stouthamer et al., 2020). These efforts have led to the development of sophisticated technical and organizational water-management systems (van Lanen & Kosian, 2020). However, changing climate conditions and evolving human-nature interactions are pushing these systems to their limits, proving them to be insufficiently resilient and flexible in the face of climate-related shocks, including floods, droughts, and loss of biodiversity (van Eldik et al., 2024). In response, approaches that shift from controlling water to accommodating it and prioritizing adaptive management practices and ecological development are emerging (Baptist et al., 2019). Examples include the Room for the River programme, which allows rivers to overflow into designated side channels (Nijssen & Schouten, 2012), and the Sand Engine (Zandmotor), a "building with nature" initiative that harnesses natural forces to strengthen coastal defense and biodiversity (Bontje & Slinger, 2017; Luijendijk & van Oudenhoven, 2019). In addition, numerous programs are exploring and experimenting with innovative approaches to support a broad transition towards more sustainable and adaptive land and water systems across diverse regions and landscape types.

In this context, we examine four projects as case studies that contribute, each in its own way, to the overarching goal of making the Dutch land and water system more resilient. These projects apply the living lab approach to address issues related to water and land management within a broad policy landscape and thus are useful in understanding the role of living labs in policymaking. The projects, namely, (i) Werken met Waterlandschappen (translated to, Working with water and landscapes) (WmW), (ii) KLIMaat Adaptatie in Praktijk (translated to, Climate adaptation in practice) (KLIMAP), (iii) Self-Supporting River System (SSRS), and (iv) Schouwen-Duiveland Living Lab (SDLL), are located in different regions of the Netherlands (Figure 5.1), allowing for a geographically diverse perspective. Access to personnel involved, as well as to information and internal project documentation was facilitated by the involvement of the second author for case studies (i), (iii), (iv), while the chief author undertook a thorough review of case study (ii). A brief overview of each case study is provided in Table 5.2.

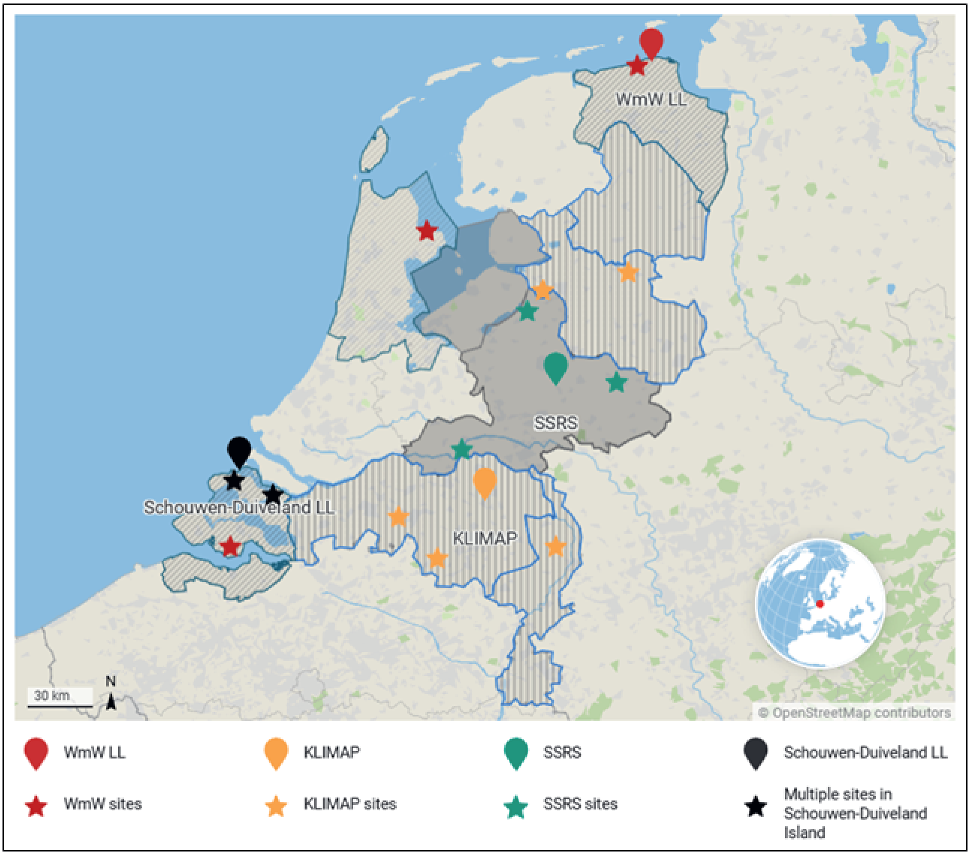

Figure 5.1.: Location of case study sites examined in this study (created with Datawrapper)

Table 5.2.: A brief introduction to all four case studies in this study

	Werken met Water-landschappen (*WmW*)	KLIMaat Adaptatie in Praktijk (*KLIMAP*)	Self-Supporting River System (*SSRS*)	Schouwen-Duiveland Living Lab (*SDLL*)
Period active:	2022-2024 Currently exploring opportunities	2020-2024 Continued through COP* and academia	1st phase: 2011-2020 & continued through several alliances	2022-2025 2nd phase of LL: approx. autumn 2025
Common aspects:	• Application of the transdisciplinary and co-creative approach • Lies within the broader topic of transition towards sustainable land and water management • Located within the Netherlands (geographically embedded)			
Innovative Goal:	To link water safety issues and well-functioning ecological water systems with the regional economy by investigating innovative business models	To investigate how the water and soil system of sandy soils can be designed to be climate-adaptive for agriculture and nature by exploring innovative measures and approaches	To explore concrete possibilities and smart collaborations based on the potential of the river area, to achieve sustainable & affordable river system management	To find new, innovative solutions to complex challenges in the areas under research themes, (i) fresh and salt-tolerant crops and freshwater supply for agriculture on land, & (ii) production of food seaward of the dike
Real-life Context:	Coastal lowlands: Exploration in: (i) Wadden coast, (ii) Scheldt coast, and (iii) Polder, for enhanced water retention and coastal defence while aiming for a well-functioning ecosystem & strong regional economy	Climate-resilient sandy soil landscape: Experimentation on water retention, crop alternatives and soil structure improvement at field scale, and exploration through development pathways at regional scale	River-systems: Experimentation of innovative ideas and applying them in practice for the transition from the current system of river management to as self-sufficient as possible	Resilient and adaptive delta island: Space to collaboratively explore innovative knowledge and action plans to overcome freshwater shortage & address ecological food production, implement the findings in practice & disseminate
Stakeholder organizations:	Partners include public organizations (ministries, province, water authority), research institutes, private companies, & organizations (e.g., nature organizations, farmer's association)	23 parties including provinces, water authorities, research institutes, farming organization, and private organizations	22 innovation partners including the executive body of the ministry, the province, water authorities, interest group, research institutes, private contractors and entrepreneurs	14 core partners; municipality, research institutes, provinces, water authorities, farming organization, nature federations, private organizations; & 12 knowledge partners, and companies
Managed by:	Primarily managed and facilitated by the research institute, with strong support from public organizations for various living lab co-creation activities	Primarily managed and facilitated by the research institute, with enabling support from public organizations	Public organization provides strategic leadership	Public organization (municipality) as project leader, while roles remain fluid, with various organizations assuming responsibility for the management of different tasks
Interviews	*4 interviewees*	*3 interviewees*	*2 interviewees*	*3 interviewees*

**COP is Community of Practices*

Semi-structured interviews (12) were conducted with the coordinators, project leaders, and other individuals actively involved in the cases. Interviewees were identified using a widely applied method in qualitative research, namely snowball sampling (Goodman, 1961). The interviewee selection started with a small group of known informants, who were then asked to recommend additional potential interviewees, leading to the full selection of interviewees. The interviews employed four open-ended questions to explore the design, activities, output/outcomes, and policy influence of the living labs, aiming to capture in-depth and context-specific insights for each project (Appendix D). A deductive qualitative analysis, as presented by Fife and Gossner (2024), was conducted in categorizing the responses to examine (i) how the projects were designed, (ii) what activities were implemented, (iii) the extent to which the goals were achieved and (iv) how (or whether) the projects influenced policy. The first three questions were used to understand the project's context, design, and outcomes, and the last question was used to understand the concrete policy contributions and the enabling factors. Since the interview focused on how these projects influenced the policy landscape, only the factors that enable policy influence were examined, and those factors that inhibit policy influence were not addressed. Multiple interviews were conducted within each project to enhance data triangulation and improve the completeness and reliability of the information gathered. Further, relevant documents and project websites were reviewed to support, validate and enrich the interview findings. Based on these analyses, conclusions were drawn about the role of living labs within the Dutch climate-adaptive water management landscape.

As this study involved human subjects, the authors developed a data management and human ethics review plan in accordance with the requirements of the Delft University of Technology, as approved by the Human Research Ethics Committee under application number 106178, where all personally identifiable information (PII) was anonymized and processed confidentially.

5.4. RESULTS AND DISCUSSION

5.4.1. ROLE OF LIVING LABS IN POLICYMAKING - BASED ON LITERATURE REVIEW

The living lab literature on public policy is gaining significant attention in recent years (Appendix D). The majority of studies are concentrated in the pre-policy, policy delivery, and post-policy support phases, with far fewer studies on policy design and evaluation (Figure 5.2). This distribution likely reflects the practical and collaborative nature of living labs, where their emphasis lies on stakeholder engagement, co-creation, and real-world experimentation over formal policy design processes, which are typically led by governmental decision-makers (Howlett & Mukherjee, 2017). At the same time, living labs lag in the systematic evaluation of their intervention and in assessing their policy impacts (Overdiek & Genova, 2021; Vervoort et al., 2022). Yet, in settings that call for collaborative, democratic approaches grounded in real-world evidence and innovation, living labs predominate. In the pre-policy phase, living labs engage relevant stakeholders to inform and influence future policy agendas by assessing the needs within real-world contexts, identifying and advocating areas requiring attention, i.e., making a case for why an issue deserves public attention, generating evidence to address them, and forming initial strategies and policy recommendations. In the policy delivery phase, living labs aim to design, test and refine innovative interventions aimed at operationalizing specific policy measures. Finally, in the post-policy support phase, living labs focus on activities such as updating and adapting policy interventions, assessing policy coherence, promoting policy integration, learning across policy domains, facilitating the upscaling of successful initiatives, and institutionalizing them for a broader policy influence. However, there is a limited empirical insight into whether, and to what extent, the evidence or policy recommendations from living labs are translated into tangible policy decisions.

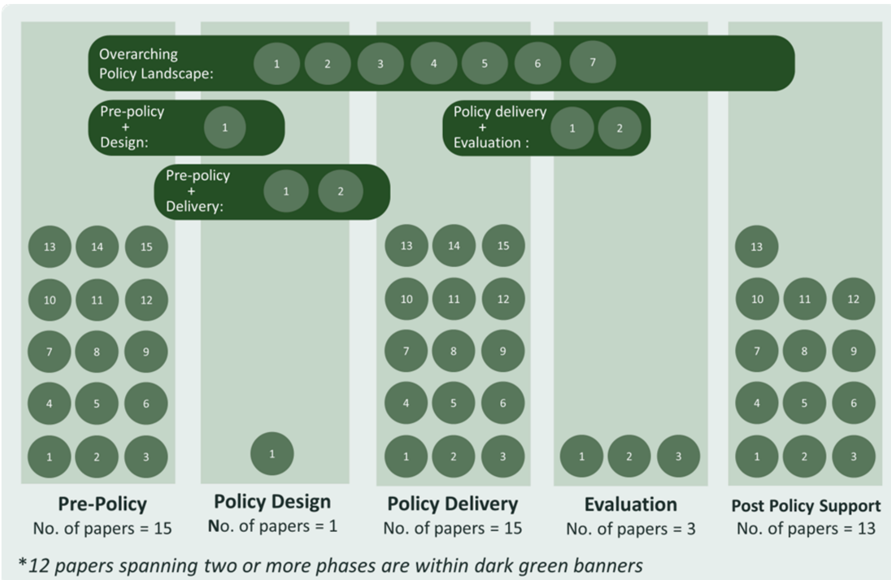

Figure 5.2.: Mapping the position of living lab literature within the phases of policy processes (details in Appendix D)

5.4.2. LIVING LAB'S POLICY INFLUENCE- BASED ON CASE STUDY ANALYSIS

Strategic and adaptive land and water management is crucial for long-term safety and resilience in a low-lying country like the Netherlands. This is supported by a wide range of national and regional policies, including the National Water Program (Rijksoverheid, 2022), the National Delta Program ("National Delta Programme 2025", 2024), and the Programmatic Approach to Large Waters (PAGW). The case studies in this research are embedded within this broader policy landscape, actively shaping the future of Dutch land and water governance.

Policy influence can take many forms, from adopting a new policy to minor adjustments in existing frameworks (Weible et al., 2012). The relationship between living labs and policy is complex, non-linear, and often temporally misaligned, in that policy changes can unfold over a longer horizon than the short-term nature of most living labs (Hossain et al., 2019). Moreover, outcome and impact assessment within living labs is complex and is often lacking (Ballon et al., 2018). It is also unrealistic to expect a fundamental transformation of long-established practices through short-lived, local-scale projects (Rollin et al., 2021). Many bottom-up living labs (Willems et al., 2023) lack institutional embedding, legitimacy, or the authority needed to influence policy processes effectively. While public innovation is often encouraged, such labs can also orient towards co-producing practical solutions that enhance public services through interactions between the local community and public authorities (Nesti, 2017). As such, not all living labs are designed to influence policy. Even in those that are, the contributions are more likely to be indirect and gradual through shaping discourse, sharing knowledge, building capacity, and nudging policy agendas over time (Kruck & Weiss, 2023). While living labs may lead to direct influence, such as establishing a new practice or regulation, most policy influence is likely to emerge indirectly through the knowledge dissemination and network-building that reshape perceptions and capacities.

Policy influences of all four case studies evolved over time, shaped by the iterative and flexible approach of living labs. In the following section, we briefly describe these cases, highlight their policy influence, and finally map them within the policymaking phases (Figure 5.3). Details of the innovative solutions for the case studies are, thus, not included in the description and can be found on the respective project websites.

A. **Working with water and landscapes (WmW)**
The WmW project focused on exploring opportunities to create multifunctional, water-retaining, buffering, and recreational coastal landscapes through nature-based design. It integrated land-use planning and hydraulic engineering with revenue-generating models, using living labs as an experimental and collaborative environment. Operating in three locations: Zeeland, Groningen, and the Ijsselmeer, WmW worked together with its stakeholders to co-create water-retaining landscapes through activities, such as design studios, formal and informal workshops, bootcamps, consultation with locals, surveys aimed at measuring public support, visiting farmers and their fields, field work including students, and so on. The two living labs in Zeeland and Groningen took an open and exploratory approach to alternative land and water management strategies, such as reward mechanisms for farmers for their ecosystem stewardship, alternative cultivation options, and 'wisselpolders' (alternate polders) with and without land exchange. 'Wisselpolder' is a system of double dikes: a primary flood defense (sea dike) and a landward dike, with an area of siltation in between that develops into a salt marsh (Terpstra et al., 2025). In contrast, the third living lab in Koopmanspolder, Ijsselmeer had a more applied focus, testing the ecological performance of the 'achteroever' (backbank) concept. 'Achteroever' is a concept of re-wetting the polder behind

the dike (Doef & van Ek, 2021). It found that 'achteroever' offers a significant benefit in managing water-levels, and for biodiversity, particularly for bird and fish populations.

These labs provided a politics-free environment that fostered learning and co-design, supported by inclusive facilitation. The first two labs in Zeeland and Groningen contributed to the discussion on innovations, such as Wisselpolders, from an economic and coastal safety perspective and the third contributed to generating evidence on the ecological value of the 'achteroever'. The explorative environment allowed stakeholders to recognize the bottlenecks of traditional measures and the need for innovative transition measures for coastal safety. The insights from WmW were connected to existing regional and national programs, such as the Programmatic Approach to Large Water (PAGW, n.d.), the Delta program, planning processes in the vicinity of the living labs, and regional implementation agendas of the national water plan, contributing both technical and social innovations to Dutch climate adaptation and water governance. An interviewee summarized, "We have different projects and programmes, and they cumulatively build-up to policy influence". WmW collaborated with diverse stakeholders to bring awareness, build trust and capacity, and provide data-driven evidence on the benefits of nature-based solutions for land and water management (such as 'achteroever' and 'wisselpolder').

B. **Climate adaptation in practice (KLIMAP)**

KLIMAP was established as a collaborative network to develop climate-adaptative land and water use strategies for agriculture and nature systems in the Dutch high sandy soil landscape. Building on a prior initiative, Lumbricus, KLIMAP introduced the use of "development pathways", a tool to plan future actions flexibly and develop capacity among stakeholders to apply these tools (Werners et al., 2021). The project investigated the effectiveness and feasibility of a wide array of interventions, including technical measures, adjustments of spatial functions, and reform in policy and regulations, which were synthesized into a practical guide, namely the 'KLIMAP Menu', to assist decision-makers and practitioners. Collaborative methods, such as co-creative workshops, participatory field experiments and visits, expert-led lectures, serious games, and other interactive formats, were employed to integrate knowledge and stimulate innovation (Bhatta et al., 2025a). Field experiments and pilot studies were conducted at multiple sites, and the localized interventions were linked with broader landscape-level planning. The field experiments included a variety of adaptation strategies, such as diversification of crop systems, enhancement of water retention capacity, and improvement of soil structure.

By iteratively employing 'development pathways' in engaging stakeholders across the high sandy soil region, KLIMAP fostered science-policy integration and built institutional capacity to apply new knowledge in policymaking. The project results were disseminated through Deltafacts, a key resource used by policy officers and experts in the Netherlands (Deltafacts, 2023, 2024). The capacity of policy actors may become an obstacle in integrating new scientific insights into policy development (Fukuda-Parr & Lopes, 2013). By fostering collaborative and iterative science-policy communications, the project helped build stakeholder capacity, enabling better use of data, evidence, and concepts in policy processes. Further, KLIMAP identified revenue models tailored to specific sub-areas and recommended subsidy measures (Bhatta et al., 2025a). The insights from KLIMAP are listed in the National Delta Program ("National Delta Programme 2025", 2024).

C. **Self-Supporting River System (SSRS)**
SSRS stands out from the other case studies as it didn't begin with a predefined concept of a living lab. Instead, it was rooted in fostering "innovation in practice for the maintenance of river systems". SSRS aimed to explore concrete, innovative solutions to manage river systems in a reliable, sustainable, and affordable manner together with public bodies, private bodies and knowledge institutes. Central to SSRS was a contractually agreed "leerruimte" or "learning space" that enabled participants to experiment, innovate and learn collectively. A few of the innovations developed via the "learning space" include light and permeable groynes, a self-propelled drone that measures water parameters (aquabot), the great bubble barrier (captures waste in water without hindering other functions), and river wood screens, while various other ideas are still the subject of experiments. SSRS is also implementing circular management practices by repurposing raw materials released during routine river management, such as wood for the wood screens, and allowing sheep grazing for vegetation management, not just as a pilot project but as a new standard approach. SSRS has characterized two groups of stakeholders: the first group participates actively in designing the innovation(s) (the pilot project(s)), and the other group forms part of the wider transition process (upscaling the pilot(s)). SSRS innovations have been applied at various sites on the rivers IJssel and Waal.

Besides innovative interventions at the operational level, the major influence of SSRS lies in (i) institutionalizing the need for co-creation and innovation through 'learning spaces' that are contractually binding, (ii) the formation of various alliances (Biomass alliance to transition towards sustainable bio-economy) and knowledge programs (Circular Land Management) to provide substantive building blocks for new policy on circularity, and (iii) connecting with other projects and living labs (e.g., Living Lab Delta East) to emphasize systemic change. An interviewee remarked, "I thought we could move to circular economy with a big leap forward, but that's not the case. We are working for over 10 years, and only now it looks like regulation is changing to include circular practices". Through its efforts, SSRS has been able to build capacity, advocate for co-creative and an innovative culture within and outside their organization, and take steps towards sustainable transition in river system maintenance.

D. **Schouwen-Duiveland Living lab (SDLL)**

SDLL considered the entire island of Schouwen-Duiveland as a living lab in implementing innovative freshwater retention strategies to design a climate-resilient landscape. SDLL engaged a wide range of stakeholders (Table 5.2) through activities such as organized excursions, field labs to test and implement innovative measures, webinars, knowledge meetings, and so on. An area-oriented approach investigated measures to hold more freshwater in different landscapes as well as at plot level, through "field labs". "Soil and water coaching" was established, where soil coaches collaborate with farmers or agricultural entrepreneurs to manage soil and reduce freshwater dependency. In addition, financial assistance was made available for farmers or agricultural entrepreneurs who wanted to implement measures in their everyday practice through "investment vouchers". Double drainage and freshwater storage in the creek ridge were among the successful measures for freshwater storage. To address the challenges with the transition process, the Taskforce Governance functioned as a learning environment, systematically exploring and providing advice on issues such as financing, collaboration, and the legislative and policy framework. The knowledge developed within SDLL was intended for dissemination through the Freshwater ('Zoetwater') Academy, tasked with knowledge transfer and capacity building in the field of freshwater management. These results were produced through digital brochures, final and partial reports, opportunity maps, and fact sheets that can be used by agrarians. The project financially supported 48 applicants in implementing these measures, the final evaluation of which is being written at the time of this publication.

SDLL has identified bottlenecks in existing policies that were not supportive of innovative implementation, thereby functioning as a reflective space for government institutions to identify areas that need to be adapted, especially for effective on-the-ground implementation. During the project, two regulatory changes took place regarding the use of materials and the design of a water basin. One interviewee noted, "The living lab was part of these institutional changes, because of the network we had and the knowledge we generated in living labs, along with other projects". For the second phase, the project wants to focus on this aspect, as an interviewee revealed, "Our ambition for the next phase is to make the whole legislative system at those governmental levels more capable of facilitating these kinds of innovations".

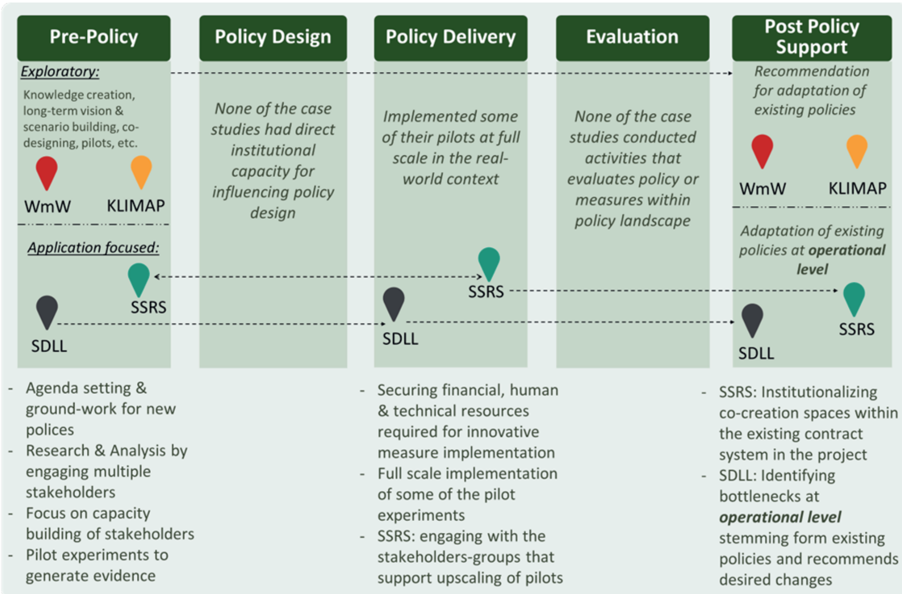

Figure 5.3.: Mapping the position of case studies within the phases of policy processes based on their policy influence

5.4.3. ENABLING FACTORS FOR POLICY INFLUENCE FROM LIVING LAB CASES

The policy process is inherently political; it is neither objective nor neutral (Sutcliffe, 2005) and there can never be a guaranteed influence over the policy process. However, individuals and organizations can position themselves to increase their likelihood of making an impact through deliberate actions (Weible et al., 2012). Drawing on the case studies, we present cumulative findings on the factors that have fostered a conducive environment for these cases to directly or indirectly influence the policy landscape (Figure 5.4). Points A, B and C examine design elements that support policy engagement, point D describes the supportive context that laid the foundation for a living lab's policy influence, and point E focuses on the output evidence linked to their policy influence. Here, it is important to acknowledge that these factors were not always easily achieved; the projects encountered various operational challenges, institutional barriers, rigid existing policies, insufficient coordination and planning, resource constraints (personnel, fund, time), covid-19 related setbacks, conflicts in ideas, resistance against innovation, instances of failed innovation, and/or feelings of frustration with long delays. Thus, navigating these challenges required ongoing reflection, continuous adjustments and strategic planning. For example, having recognized the time constraints imposed by the seasonal demand of the work for farmers, the WmW project scheduled its atelier sessions before or after the peak farming seasons, ensuring that farmers could participate.

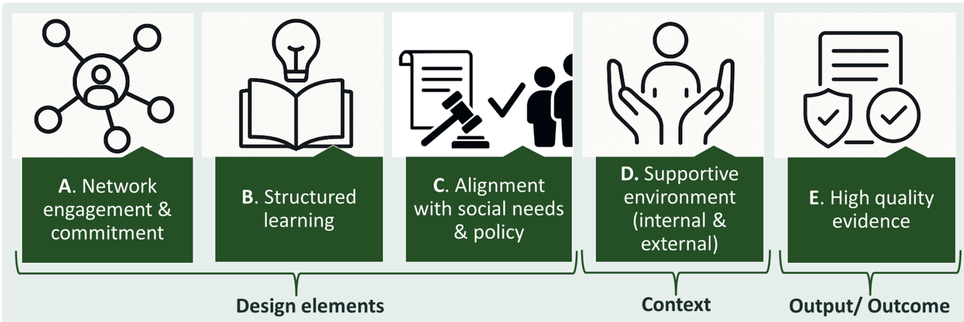

Figure 5.4.: Enabling factors for policy influence from living lab cases

A. **Network engagement and commitment**
Interorganizational co-operation, often considered valuable for a successful policy contribution (Brynard, 2009), is a characteristic feature of a living lab environment. However, such co-operation is meaningful only when the stakeholders demonstrate ownership and commitment (Brynard, 2009). As such, interorganizational (quadruple-helix) and sustained stakeholder engagement was evident across all cases. In all cases, most of the key stakeholders remained involved from the project inception to its closing. In WmW, stakeholders were invested in developing business models for nature-based solutions in the context of coastal safety. This commitment led some stakeholders to actively initiate learning across different locations and implement additional projects. The network expanded progressively as more farmers and interest groups became involved. Additionally, in one of the locations, a 'Burgerraadpleging' was established, which is a way of consulting with citizens. Many stakeholders in WmW had double roles, making it easier for them to bridge across different sectors. KLIMAP leveraged a part of the existing network of its predecessor project, Lumbricus, and expanded it with new organizations. The stakeholders brought the project actions back to their organizations, as one interviewee noted, "We are ambassadors of climate adaptation measures for our respective organizations".

Likewise, SSRS aimed not only to integrate diverse knowledge for innovation, but also to foster strong relationships among participants, boost shared ownership of the problems, and distribute the risks associated with innovation. Unlike traditional roles, where private organizations engage transactionally, academia holds an advisory role, citizens are rule-abiders, and government functions as regulator or funder, SSRS was able to establish a co-creation network with these stakeholders to pursue innovation. One interviewee remarked, "When you switch the traditional way of working, you have to remind yourself that you are all working together on an equal basis." The commitment was established through contractual agreements. SDLL focused on building strong collaboration by maintaining an open and agile network.

Many key stakeholders exhibited a strong sense of commitment to the project objectives. As a few interviewees noted, “Many of us have some passion with the area and/or with the topic”, i.e., they felt ownership and responsibility towards the project as the island was their residence, and they were passionate about the topic.

These projects are more than just isolated instances; they are part of a longer chain, with other projects either preceding or succeeding. However, not all the associated projects have chosen to adopt a living lab approach. WmW’s work is guided by the ambition to develop “future-proof large waters where thriving ecosystems coexist with a robust economy”, in alignment with the national investment program, namely the Programmatic Approach to Large Waters (PAGW, n.d.). WmW’s work at different locations is being continued through various other programs. For instance, the experiment of Ijsselmeer started long before WmW and is being continued through other Top Consortium for Knowledge and Innovation (TKI) projects, and the idea is continued at other locations, e.g., in Friesland and Flevoland. Further, drawing on the insights of ‘achteroever’, a public-private partnership occurred with the drinking water company. KLIMAP has been succeeded by been succeeded by Community of Practice (COP) and academically oriented projects, such as the CAtchment Strategies TOwards Resilience (CASTOR) and NATure-based approaches for climate-robust, sustainable and productive sandy-soil landscapes (NAT), and is continuing its knowledge development through activities within several organizations and projects (NWO, 2025). Similarly, SSRS has been one of the longest-running case-studies and its way of working and thinking is being extended through many other initiatives and networks, e.g., Circular terreinbeheer. Likewise, SDLL will continue its living lab with renewed goals, starting in autumn 2025. This pattern of continuity enables gradual reforms by building up the evidence from individual projects (Kruck & Weiss, 2023). Since a living lab’s influence in the policy landscape does not result only from of a single project but rather from a network of similar projects, they must focus on collaborative endeavors that incrementally build a wider body of work, and that develop longer-term relationships with a range of non-academic audiences (not only scientists, policymakers and other ‘elites’) (Boswell & Smith, 2017). Further attention is required to make living labs inclusive, representative, open, and equal.

B. **Structured Learning and Evaluation**

Another prominent feature across the case studies is the explicit emphasis on “learning” as an integral component of project design and implementation. WmW used living labs as a “learning environment” to foster and disseminate knowledge within and beyond the project. KLIMAP focused on various forms of learning and organized “learning sessions” (Bhatta et al., 2025a), SSRS designed “learning spaces” to co-create innovative solutions in theory and experiment with them in practice, as one interviewee remarked, “knowledge is the backbone of leerruimte”. Likewise, SDLL established a dedicated network, the

‘Zoetwater’ Academy, to capture and disseminate freshwater-related knowledge and Taskforce Governance to facilitate the living lab (e.g., by conducting stakeholder mapping, recognizing policy bottlenecks, and adapting the rules). Apart from such structured learning, informal networks also play a powerful role in knowledge sharing in living labs. Recent studies on living labs have highlighted the significance of learning in living lab environments for their operation and dissemination; and have demonstrated that various types of learning occur at different levels and in different ways (Bhatta et al., 2025a, 2025b; Herth et al., 2025). Similarly, learning plays an enabling role within policy processes (Radaelli, 1995; Weible et al., 2012). When rooted in learning, policies tend to carry enhanced legitimacy, the likelihood of uptake increases, and policies are more likely to be socially supported (Argyris & Schön, 1996; Mukhtarov et al., 2019).

However, it is important to note that although the (physical) interventions in these projects were often monitored and evaluated, no formal form of project evaluation was present in any of the case studies. In the case of SDLL, however, a learning evaluation was present. Evaluating interventions allows measuring the degree to which the desired goals are achieved. However, a full project evaluation is important to capture the consequences of the project at the individual, interpersonal, and collective levels and thus, the project’s output, outcome, and impacts.

C. **Social and Policy relevance**

Drawing on both top-down and bottom-up strategies, a living lab can become a part of transformative institutional change that combines policy-driven (top-down) coordination with entrepreneurial or citizen-empowered (bottom-up) initiatives (Cai & Lattu, 2022). The core content that was explored, experimented, and implemented in the case-studies had clear policy and social relevance, i.e., is compatible with public needs. With the changing climate and increasing risk of droughts as well as floods, topics such as designing resilient agriculture practices, developing freshwater security, enhancing flood-protection, embracing nature-based solutions, and increasing biodiversity are increasingly becoming topics of public interest. Such topics, based on social need and local identity, led to an invested network of stakeholders, as was observed in all projects. Further, the topic of land and water is integrated within the broader Dutch policy framework (van Eldik et al., 2024), enhancing their relevance to the existing governance structure. In the Netherlands, land and water-related challenges have long held a central position in public governance, owing to the country’s geographic and historical context (van Lanen & Kosian, 2020). As a result, the topic of land and water management is deeply embedded in both institutional policies and the priorities of policymakers, requiring ongoing adaptation and innovation. One of the interviewees from SDLL noted, “We wanted to implement the measures within the project timeline, so we aligned with existing policies to ensure relevance; but we weren’t just following the policy because that would mean no innovation".

Given that attention is a crucial yet scarce commodity in politics and policymaking, and gaining attention is a prerequisite for public issues to reach policy agendas (Liu et al., 2010), the topical relevance of these projects could have increased the visibility of these case studies within ongoing governance processes. All the projects secured a multi-sectoral funding stream from different sectors, primarily from the government sector. WmW was an initiative of Knowledge and Innovation- Agenda Agriculture, Food, Water and was financed by several government organizations. The major sources of funds for KLIMAP were TKI Agri & Food, TKI Water technology, NWO, and engaged governmental organizations, i.e., provinces and water authorities. SSRS is a government initiative with funding primarily from Rijkswaterstaat (National Water Authority), ad-hoc funding from TKI, and a few cases of private investment. Finally, SDLL was realized with support from the Intergovernmental Program Vital Countryside Southwest Delta (IBP-VP-ZWD), EU contribution through third Plattelandsontwikkeling programma (POP3), and subsidy from the province of Zeeland and the municipality of Schouwen-Duiveland, with on-field intervention partially realized via the entrepreneurs' private funds. However, having reasonable social and policy relevance isn't enough, as one interviewee from WmW remarked, "Sometimes it's not about institutions but people in those institutions. We need to find the right people in the right institutions to go further with the innovations, but it's more important to realize where the resistance lies and why, so that we can tackle the issue and talk to them".

D. **Supportive Environment**

A supportive internal and external environment is another important factor that enables policy influence in case studies (Brynard, 2009). In all case studies, there was a project management structure and a specific person in the role of project leader, facilitator, or coordinator, who steered the project in a desired direction, balanced with the freedom to organize individual activities and tasks. In addition, WmW focused on providing a politics-free space where participants could learn freely and design together. One of the interviewees noted, "There was an open atmosphere to speak one's mind, but also be open to others' ideas. That is about mindset. And we could create a politics-free exploration and learning space, also due to the right type of facilitation. It was a different kind of leadership; not simply leading but bringing people together." Another actor remarked, "We could create a non-political environment while engaging with political people". In KLIMAP, attention was paid to ensuring neutral communication and finding a balance in dealing with sensitive topics (Bhatta et al., 2025a). Similarly, as a pioneer of sustainable and innovative river system management, the SSRS project had to prove the value of its work. The project wanted to be an example for transition, as one of the interviewees noted, "Along with our team, we also wanted to take our institutions ahead with us in our innovation transition endeavor. As we became more successful in our pursuit, we saw members of our institution change their perspective too". As such, the public body stakeholders from SSRS had access to various government levels and were better positioned to share learning and influence others. At SDLL, implementing certain innovations in practice was made possible through regulatory exceptions, and the living lab approach facilitated these discussions. As such, all the case study projects received active attention from representatives of public organizations, as evident from their time commitment, financial contributions, and the deliberate efforts to connect the project with other ongoing initiatives in their organizations. Such expansive involvement from public organizations has been revealed to be one of the factors contributing to policy influence (Adamo, 2002).

While all the case studies started some kind of transformative movement in their respective policy landscapes, the extent to which the output of these case studies influenced policy is largely shaped by external political dynamics (Head, 2010). In response to the challenge of changing climate and intensive use of land and water, as evidenced by widespread research ("Water Verbindt", 2021), the Dutch cabinet 2022 introduced 'Water en bodem sturend', i.e., 'Water and soil guiding' as a foundational principle for future spatial decisions ("Water-Bodem-Sturend," Nov, 2022). This marked an important transition step towards respecting the limits of the natural system by adopting a long-term sustainable land management strategy (van Eldik et al., 2024). While the national government, provinces, water authorities, and municipalities, including the ones involved in our case studies, were exploring ways to put this policy guideline into practice, the subsequent Dutch cabinet 2024 revised the 'water and soil guiding' into 'take water and soil into account', retreating from the earlier planned transformation. However, the 2024 cabinet has since collapsed, leaving the future direction of this policy guideline contingent upon the political orientation of the next governing cabinet. This example is indicative of how political truths can be distinct from facts (Hannon, 2023), and that policy uptake and implementation ultimately remain subject to political will and priorities. Despite this, some local governments and water authorities, including some in this research, plan to leverage their autonomy to continue implementing the transition efforts. One of the interviewees remarked, "We already had a plan in place to continue our transition efforts. And it also helps that the recent cabinet that reversed the policy guideline has also fallen". Several interviewees from the case studies mentioned that the materialization of their influence depends on being able to utilize a "policy window" (Kingdon, 2003) where issues, policy, and politics come together.

E. **Creating and delivering high-quality project outputs and outcomes**
Producing high-quality output is closely connected to creating a well-designed learning environment (Bhatta et al., 2025b). A multi-analytic or interdisciplinary approach, combined with local knowledge through co-creation, is foundational for policy output across local to national contexts (Weible et al., 2012). Due to their multi-sectoral and multi-disciplinary characteristics, living labs can

provide a transdisciplinary space where diverse stakeholders co-create products, tools or services through iterative exploration and experimentation. Given their flexibility to adapt the methods, activities, and experiments to evolving context and conditions, they can generate highly relevant and context-sensitive outputs. Producing relevant and high-quality research output contributes to policy influence (Adamo, 2002). Moreover, the visibility and prioritization of specific topics are frequently associated with the role of mass media and advocacy (Knill & Tosun, 2008). Therefore, integrating diverse dissemination strategies and policy perspectives into communicating the project results is important in effectively conveying insights and maximizing policy relevance. Further, sharing successful innovations is also important to inspire other regions to replicate the innovative practices. As more areas adopt similar practices, cumulative evidence can build a compelling case for policymakers to drive higher-level policy changes.

The major outputs of WmW are insights on potential business models in the coastal area while enhancing biodiversity. In Groningen, an additional project with the public organization was conducted to develop pathways for coastal zones until 2120. Regarding the 'achteroever' concept in Koopmanspolder, one interview remarked, "We have many frameworks such as Natura2000, Water Framework Directive, all of which focus on long-term future, but implementing innovative measures today is very hard. Because there is always resistance to new things. In our case, we also won some awards, and these little wins kept us energized". The insights from the project were published in knowledge magazines such as "Water Governance", and "H2O", to reach wider audiences. KLIMAP has produced high-quality knowledge and research output on water management and agricultural practices for sandy soil landscapes, published in Delta Facts (an online knowledge record in the field of water management, consulted by water managers). These activities generated practical knowledge on the performance and scalability of such interventions. Likewise, SSRS developed problem-driven innovative measures for river management (section 5.4.2), used technology readiness level to indicate their maturity and stakeholder readiness level to measure the stakeholders' acceptance, and made decisions on intellectual property. It adopted a holistic approach, focusing on the entire supply-to-demand chain to enable complete transition management. Additionally, it identified relevant stakeholders beyond the SSRS team, crafting relevant stories to improve alignment with stakeholders' interests. Further, it addressed challenges related to policy uptake, e.g., by providing evidence for policymakers with reliable data through monitoring innovative measures, thus enabling them to take steps towards transition. SDLL followed an action-oriented learning-by-doing approach. The focus was not just on exploring and experimenting with innovations at a pilot-scale, but on realizing them at a real-world scale, recognizing that insights from full-scale implementation are more credible than those from small-scale pilots. The project has significantly increased freshwater availability and infiltration capacity (over 400,000 m3), marking a step towards farmers' freshwater self-sufficiency. The project was also featured in the Dutch DeltaProgramma 2023.

5.5. CONCLUDING REMARKS

This paper explores the non-linear and complex dynamics of living labs within the policy landscape. Living labs are simultaneously shaped by and are shaping the policy landscape. The literature review revealed that living labs within policy processes remain in an early stage, gaining more traction in recent years. Most studies focused on the pre-policy, policy delivery, and post-policy support phases, where living labs contributed to generating scientific and contextual evidence, engaging stakeholders in exploring new policy directions, testing innovative interventions, and promoting policy integration. The analysis of four Dutch projects applying the living lab in the context of climate-adaptive water management demonstrated varying influence on policy. The WmW and KLIMAP projects primarily focused on creating knowledge to achieve climate-resilient landscapes. These projects allowed stakeholders and policymakers to understand the challenges better and explore innovative solutions by integrating knowledge from science and society into water-relevant policy. Their broader policy influence can be expected to emerge gradually over time, as part of a cumulative, long-term process. In contrast, the SSRS and SDLL projects demonstrated more immediate operational influence by embedding co-creation processes and prompting regulatory adaptations within local governance structures. Drawing from these cases, several interrelated factors emerged as critical for enabling policy influence: (i) strong stakeholder engagement and commitment; (ii) an emphasis on structured learning; (iii) alignment with both societal needs and the broader policy agenda; (iv) the presence of a supportive institutional and political environment; and (v) the generation of credible, high-quality evidence. Furthermore, the findings suggest that living labs tend to have greater influence when connected to networks of similar projects, primarily due to the richness of their evidence and the wider reach of the larger stakeholder network. Without such alliances, however, they risk remaining fragmented and short-lived, with limited influence on systemic or regulatory changes.

The case studies in this research examine Dutch living labs operating within the specific policy context of climate-adaptive water management. Therefore, the conclusions regarding their role in informing, supporting, and influencing policy processes are shaped by sectoral and national contexts. As a country recognized internationally for water management, insights from Dutch living labs can contribute to EU policy learning and innovation. These labs embody the EU's commitment to inclusive, place-based innovation and offer a globally relevant model for participatory governance and climate adaptation. This study has several limitations. The scope of the literature review was restricted to living labs explicitly linked to policy processes, excluding related approaches such as policy labs and citizen labs, despite their conceptual overlaps. Future research should explore these other policy-related labs to develop a more comprehensive understanding of their roles and impacts. Additionally, the study focuses on factors that enable policy influence, and not on those that constrain it. Living labs also face several significant challenges in influencing policy processes. These include the lack of a longitudinal framework for living lab evaluation, insufficient mechanisms to ensure continuity over time, limited social and institutional integration, and undeveloped systems for systematically capturing knowledge to support evidence-based policymaking. As one of the early studies examining the influence of living labs in policy processes, this research calls for further inquiry. Key questions are: How effective and useful are living labs compared to other policy tools? How can living labs be designed for diverse policy landscapes? How can the policy landscape itself become more receptive to living lab outcomes?

6

CONCLUSION

This dissertation examines living labs in the field of land and water management through the metaphor of plant cultivation. Taking the cultivation metaphor offers a structure and intuitive framework for understanding the origins (seeds), learning (roots), outcomes (harvest), and influence on the policy (landscape) of living labs. This metaphor is reflected in the titles of chapters 2 to 5, and Figure 6.1.

A. The seeds for the living lab approach were already sown long before the term was coined. Early traditions of participatory design, user-driven innovation, action research, real-world experimentation, triple-helix innovation, iterative design, and agile methodologies, among other concepts, laid the foundation for living labs. Over time, the living lab approach branched into different contexts, additional application domains, and geographical regions, gradually obscuring its core characteristics. Thus, *the first contribution* of this research is to distill and clarify the core characteristics of living labs by drawing on and synthesizing over two decades of literature on their evolution (chapter 2). Possible variations within these core characteristics are also identified. With this, the research provides a much-needed information synthesis for researchers and practitioners, especially those new to the field, presenting an overarching understanding of living labs, their evolution, defining characteristics, and variations within those characteristics.

B. The *second contribution* lies in anchoring living labs in appropriate and robust theoretical foundations (chapter 3). Learning theories applicable to living labs are explored, and a "living lab learning framework" is developed, rooted in these theories. Just as roots provide stability and nurture plants, the roots of these learning theories offer stable foundations to living labs, connecting them to the broader knowledge system. The learning framework can serve as a tool to support the analysis, monitoring, and evaluation of learning processes within living lab activities. The framework is designed to be dynamic rather than static. It enables capturing of the learning outcomes and the broader impacts that extend beyond immediate project results, thereby enhancing the strategic value and effectiveness of co-creative initiatives.

C. The *third contribution* of this research stems from the application of the learning framework to harvest living lab outcomes through learning pathways, which are both tangible and intangible (chapter 4). Tangible outcomes include product prototypes, tested solutions, innovative methods, and policy changes. Intangible outcomes include the lessons learned, the knowledge created, new capacities and skills, strengthened networks, and established relationships. These pathways enable actors to better understand the outcomes of their collaborative efforts, identify valuable lessons, and apply the insights to future initiatives.

D. The cultivation metaphor also offers insights into living labs as embedded within existing landscapes of governance and culture (particularly related to land and water management) rather than as isolated "projects". Thus, the *fourth contribution* of this research comes from understanding the influence of living labs within the broader policy landscape and factors enabling such influences (chapter 5). Supportive policies, institutions, and receptive communities serve as enabling conditions for the policy influence of living labs, much like nourishing rain for plant growth. Conversely, conditions such as rigid regulations, short-term funding, or conflicting agendas can be detrimental, much like drought. Yet, just as plants can alter landscapes by stabilizing soil or creating shade, living labs can also shape their environments by influencing policy, fostering incremental or systemic change, and contributing to more resilient futures.

From the seeds of the past to their roots in learning, from harvesting tangible and intangible outcomes to the shifting landscapes of policy and society, living labs embody both fragility and resilience. They require ownership, perseverance, and the active participation of many to harvest the desired outcomes and ensure impact on their landscape. This framing of living labs through a cultivation metaphor highlights that living labs are not only about producing short-term innovations, but also about building long-term knowledge, developing capacities & resilience, and cultivating networks in their fields of application through their learning environments and potential policy influences.

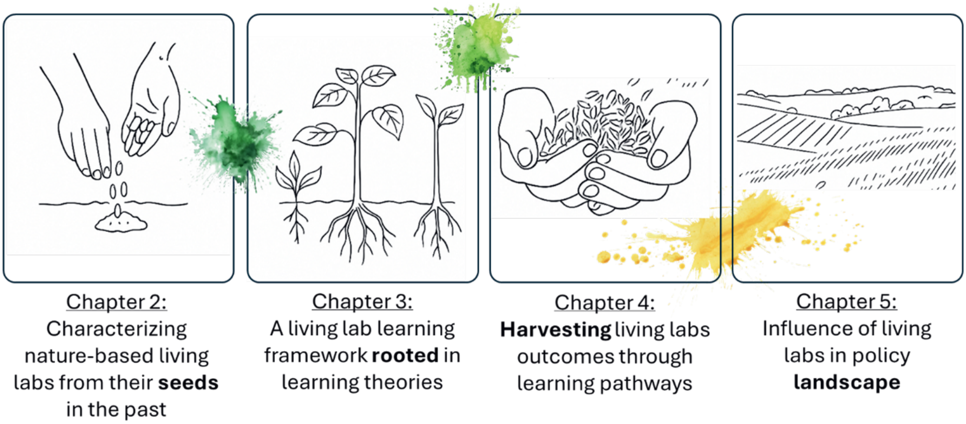

Figure 6.1.: The contributions of chapters 2-5 within the plant cultivation metaphor

6.1. ANSWERING THE RESEARCH QUESTIONS

This dissertation advanced the understanding of living labs and their effects, particularly within climate-adaptive land and water management by addressing the four research questions (see Figure 6.2 for integrated illustrative conclusions).

RQ.1) What are the core characteristics of (nature-based) living labs?
By analyzing the historical development of living labs through literature review, the core characteristics of living labs were identified. While early living labs primarily focused on ICT and technological innovation, over time, living labs evolved to include diverse applications and geographical domains. Their scope broadened to encompass application domains such as health, energy, and nature-based solutions, and geographical settings varied from urban to rural and even university campus localities, among others. The core characteristics of living labs were identified as: 1) Real-life settings *(i.e., experimentation occurs in authentic environments)*, 2) Pursuit of innovation *(i.e., focus on creating and testing new solutions)*, 3) User-centric approach *(i.e., active involvement of end-users in co-creation)*, 4) multi-actor involvement *(i.e., collaboration among diverse stakeholders, particularly quadruple helix)*. These characteristics form a foundational framework for understanding living labs. The research also identified contextual variations within these characteristics and highlighted the unique characteristics of nature-based living labs, such as a focus on sustainability, particularly in the use of materials.

RQ.2) How can learning be conceptualized and operationalized within the co-creative environment of living labs?
Here, a novel analytical living lab learning framework grounded in learning theories was developed. Nine learning theories, relevant to the characteristics of living labs with a focus on sustainability and cognizance of digitalization, were identified. They are: *behaviorism, cognitivism, constructivism, experimental,*

situated, social, organizational, transformative, and *connective* learning theories. The nine theories were evaluated by answering three major questions: "What type of knowledge is produced?", "How does learning occur in a specific learning theory?", and "Who is learning?". These guiding questions formed the basis of an analytical living lab learning framework. The framework categorizes learning into *types, processes* and *levels*. Here, *'Types'* refers to the nature of the knowledge shared and created, further classified as content, capacity, and network; *'Processes'* is understood as the method of acquiring learning, classified as intentional or incidental; and *'Levels'* concerns the entities involved in learning, classified as individual, team, organizational, and systemic. The framework provided an epistemological basis for living lab learning to capture the often-overlooked learning outcomes of these innovative environments and enhance the configuration of living labs as co-creative learning environments.

RQ.3) How can living labs contribute to learning outcomes, particularly in the field of land and water management?
The third research question emphasizes the way in which learning in co-creation activities can contribute to living labs' overall success by enabling the identification of outcomes and broader impacts. This research applied the analytical learning framework under RQ.2 to harvest learning outcomes of the KLIMaat Adaptatie in Praktijk (KLIMAP) case through learning pathways. This ex-post analysis, conducted using surveys and interviews, systematically documented sequences of learning activities and revealed seven distinct pathways, which are: 1) harnessing collective, integrated knowledge, 2) building collaborative networks, 3) enhancing stakeholder capacity, 4) adapting and contextualizing knowledge, 5) innovation diffusion, 6) facilitating co-creation, and 7) reflecting and learning. Each pathway highlights learning activities, categorizing learning type, process, and the involved entities, and their outcomes. In KLIMAP, this approach revealed seven distinct pathways, though the number and nature of pathways may differ for other living labs. By making the knowledge generated in KLIMAP explicit, these pathways enable actors to understand and reflect on the outcomes of their collaborative efforts, identify valuable lessons, and apply these insights to future initiatives. Overall, the findings demonstrated how structured learning pathways can harvest the deeper, often overlooked effects of co-creation processes.

RQ.4) How can living labs contribute to policy development, particularly in the field of land and water management?
Collaborative approaches, such as living labs, represent an emerging model of dynamic and innovative governance that establishes new networks among the stakeholders, facilitates mutual understanding of needs and capabilities, and enhances shared knowledge of complex societal problems (Innes & Booher, 2003). However, such collaborative modes of governance are far from the mainstream policy discourse and are not universally applicable across all policy contexts (Innes & Booher, 2003). Thus, the fourth research question investigates how living labs interact with policy processes, mapping their

contributions across five phases: pre-policy, design, delivery, evaluation, and post-policy support. A review of living lab literature related to policymaking processes revealed that most studies are concentrated in the pre-policy, policy delivery, and post-policy support phases. In the pre-policy phase, they engage stakeholders to identify needs, build evidence, and propose initial strategies and recommendations; in the policy delivery phase, they focus on designing, testing, and refining interventions to implement specific measures; and in the post-policy stage, they provide support in updating interventions, ensuring policy coherence, scaling successful initiatives, and institutionalizing them for broader impact.

Four living lab cases in the Netherlands within the field of climate-adaptive water management, namely, *Werken met waterlandschappen (WmW), Klimaat Adaptatie in Praktijk (KLIMAP), Self-sufficient River Systems (SSRS)*, and *Schouwen-Duiveland Living Lab (SDLL)*, were explored to understand their positioning within the policymaking phases, their policy influence, and the factors enabling such influence. The cases demonstrated varied influences; some impacted Dutch policy directly via operational regulatory adaptation, while others contributed indirectly by generating context-specific evidence and fostering long-term stakeholder learning. The analysis identified five factors enabling the policy influence of these living labs, namely: (i) strong stakeholder engagement and commitment, (ii) emphasis on structured learning, (iii) alignment with both societal needs and broader policy agendas, (iv) supportive institutional and political environments, and (v) generation of credible, high-quality evidence. Nevertheless, questions remain regarding the scalability, institutionalization, and long-term policy relevance of living labs, highlighting the need for comparative research to situate them alongside other participatory policy tools.

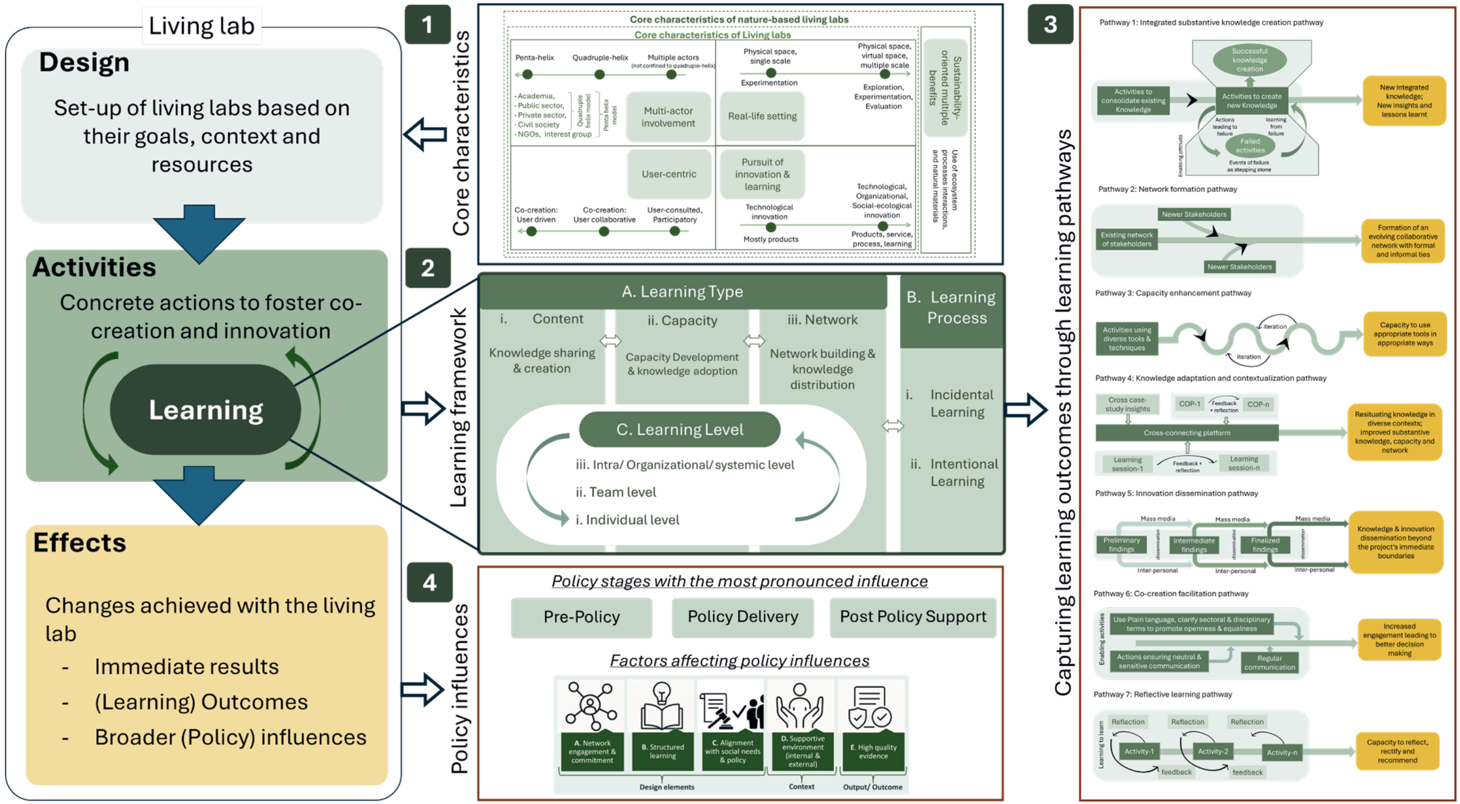

Figure 6.2.: Synthesis of insights from chapters 2 to 5 forming an integrated conclusion addressing the four research questions (indicated by numbers 1, 2, 3, and 4)

6.2. REFLECTIONS ON THE RESEARCH

The dominant narrative surrounding living labs is largely a positive one, portraying them as inclusive and co-creative platforms with significant potential for innovation. This dissertation adopts a similarly optimistic stance regarding the capacities and potential of living labs. They create conditions for innovation by allowing room for risk-taking, providing access to funding, and operating alongside established organizational structures. However, the effectiveness of living labs is not inherently guaranteed by the concept itself (Paskaleva & Cooper, 2021), rather, it is contingent upon how the approach is implemented in practice. As a methodological framework, living labs provide the structural conditions for co-creation and innovation, but their success depends on, among others, the quality of stakeholder engagement, the strength of collaborative relationships, social and relational capital, and the sustained commitment of participants (Paskaleva et al., 2015). It is through these dynamic human and institutional interactions that living labs generate meaningful and impactful outcomes.

Another observation is that what constitutes success within living labs is insufficiently addressed. Often, co-creation in living labs is seen as 'virtue in itself' (Dekker et al., 2021; Voorberg et al., 2015). Should the mere implementation of co-creation processes or adherence to living lab characteristics be regarded as an achievement in itself, or should success be evaluated based on the extent to which these processes lead to the desired innovations? When success is measured solely by conformity to living lab principles, it overlooks the ultimate purpose of living labs and weakens their potential to deliver impactful and desired innovations. But this is followed by another question: what is the desired innovation of living labs? Is it limited to the immediate results, or does it also include a longer-term outcome or impacts at a broader level beyond the immediate outputs? As identified in this dissertation, living labs are useful in producing broader impacts and influence; thus, defining their effects should extend beyond their immediate output.

Additionally, the current landscape of living lab research reveals a significant gap in systematic evaluation practices. Investigations to understand the performance of living labs and their capacity to produce applicable knowledge are limited (Paskaleva & Cooper, 2021). There is a need for structured evaluation frameworks that can capture both the intended and unintended consequences of living labs. A longitudinal evaluation framework, such as the living labs learning framework (chapter 3 in this thesis), provides a means to assess the impact over time, which can strengthen accountability and deepen understanding of how learning unfolds in complex, real-world innovation ecosystems, ultimately shaping their broader impacts. A lack of evaluative clarity undermines the transferability and scalability of the insights and practices, making it difficult for living labs to be socially or institutionally integrated and limiting their potential as mechanisms for evidence-based knowledge generation.

Another reflection concerns the term "living lab" itself. Despite its growing popularity, many initiatives labelled as living labs do not actually embody the core principles of the approach. In some cases, the term has become politically and strategically charged—used for its appeal, branding value, to align with funding priorities or dominant innovation narratives—a phenomenon that has been described as “lab-washing” (Joost et al., 2025; Paskaleva & Cooper, 2021). Conversely, many initiatives that adhere to living lab principles aren’t explicitly identified as such. This may occur due to project continuity under different names, stakeholder preferences, contextual adaptations to local communities, or cultural and linguistic considerations. Outside the European context, the term’s reception is not uniformly positive, prompting the use of alternative framings such as city labs (Scholl & Kemp, 2016), place-based innovation (Rissola et al., 2017), or community-based co-creation (Greenhalgh et al., 2016). This divergence underscores both the conceptual fluidity and the contested politics surrounding the living lab discourse.

Further, there are several interactive and creative spaces that resemble living labs, including intercultural participation spaces (Enserink et al., 2007), co-productive design spaces (d’Hont & Slinger, 2022; Slinger et al., 2023), policy labs (Hinrichs-Krapels et al., 2020), and transformative spaces for sustainable transition (Pereira et al., 2020). While these approaches share participatory and experimental features, they originate in distinct epistemic communities and therefore differ fundamentally in their intent. For example, policy labs that are rooted in public administration focus primarily on experimenting with policy instruments and governance arrangements (Hinrichs-Krapels et al., 2020), while transformative spaces, emerging from sustainability science, explicitly aim to enable structural change and deep systemic transformation (Pereira et al., 2020). Living labs, by contrast, originated in innovation studies and are primarily oriented toward real-world experimentation to co-create and validate innovative solutions. This research has focused on examining how living labs foster learning through experimental co-creation activities and how they influence policy by translating experimental outcomes into actionable solutions.

Reflection on methodological choice:
The methodological approach adopted in this research, which combines systematic literature reviews with empirical case studies, was shaped by both conceptual gaps and practical constraints in the field of living lab research. The theoretical foundation for learning within living labs was provided by exploring and identifying learning theories (chapter 3). The limited scholarly attention to learning within living labs, evidenced by only a handful of peer-reviewed studies at the time of inquiry, necessitated an innovative strategy for theory development. Consequently, learning theories were mapped against the defining characteristics of living labs so as to construct a robust conceptual foundation despite the fragmented literature. Accordingly, the learning theories identified as corresponding to individual living lab attributes were analyzed and evaluated for their applicability and relevance to the overall conceptual framework of living labs.

Applying the ‘learning framework’ developed in chapter 3 within an empirical case (chapter 4) provided insights into its practical relevance and applicability. Adopting a pragmatic stance, the research focused particularly on the “learning types” component of the framework, using it as a lens to map and interpret the diverse learning pathways retrospectively in the case study. This allowed for a nuanced understanding of how learning unfolded in practice within a living lab environment, while also highlighting the importance of embedding systematic learning assessment into living lab design from the outset. Similarly, chapter 5 explored the positioning of living labs within policy processes, followed by an empirical analysis of four Dutch cases within the context of land and water management. The findings suggest that living labs cannot be assumed to exert policy influence by virtue of their design alone; rather, their effectiveness depends on deliberate strategies for institutional embedding and long-term collaboration.

As largely theoretically informed empirical research, the methodological choices in this dissertation reflect a pragmatic balance between conceptual rigor and empirical feasibility. The approach of linking theoretical frameworks with empirical case studies strengthened the research's contribution by capturing, in an analytical manner, the role played by living labs in fostering learning as well as in influencing policies under specific conditions.

6.3. Research limitations and future studies

Although the specific limitations and potential future direction concerning individual chapters are discussed within the respective chapters, this section addresses the overarching limitations that influence the research as a whole. It identifies the broader constraints that shaped the study's design, implementation, and interpretation of findings.

Research Generalizability:

This research primarily focused on living labs in Dutch land and water management, with particular attention to nature-based living labs (NbLLs). Although NbLLs are not explicitly highlighted throughout the study, all the case studies partly or fully experimented with and applied nature-based solutions. Given the existing diversity within living labs, the living labs discussed within this research may perform differently from those in other domains, such as technology or health. Another limitation lies in the generalizability of the case study results. While the learning framework is grounded in a systematized theoretical system, making it applicable in various empirical studies, the learning pathways were developed within a single case study in the context of Dutch governance, where sustainable land and water management are a priority (Pot, 2024). Thus, it is unclear how reflective the KLIMAP case study is of other complex, real-world challenges in different regions and governance systems worldwide. Pathways for other living labs can be different based on their design, socio-political position, and operationalization. Likewise, to identify factors enabling living labs' policy influence, this research examines Dutch living labs operating within the specific policy context of climate-adaptive land and water management. Therefore, the conclusions regarding their role in informing, supporting, and influencing policy processes are shaped by both sectoral and national contexts. More empirical study in other fields, and regions with diverse socio-political, cultural, and economic settings, therefore, is needed to improve the applicability of the framework and the generalizability of factors enabling living labs' policy influence.

Data limitations and bias:
Like many studies, this research encountered data limitations. One key limitation lies in its exclusive focus on peer-reviewed academic journals, which narrows the scope of analysis. As living labs are inherently practice-oriented, gray literature likely holds valuable insights that could enhance and broaden our understanding of living lab knowledge. These have not been systematically included in this research. Moreover, because peer-reviewed publications are predominantly authored by academics rather than practitioners or policymakers, this focus may have restricted the representation of perspectives from those directly engaged in the implementation and management of living labs. In addition, many "lab concepts" similar to living labs exist in parallel to living labs, such as innovation labs (McGann et al., 2018), real-world laboratories (Huning et al., 2021), policy labs (Hinrichs-Krapels et al., 2020), citizen labs, and so on, but were not investigated in this research.

As previously mentioned, the empirical case studies utilized in this research are geographically limited, thereby constraining the diversity of data sources. Similarly, the literature review also does not investigate the potential variations stemming from the geographical contexts of the studies examined. Further, this research mirrors a Eurocentric orientation that characterizes much of the current living lab literature. This bias, while reflective of the concept's historical development and institutionalization within European innovation policy, highlights the need for greater engagement with perspectives and practices emerging from other regions, where the concept may be interpreted, adapted, or even challenged differently. This study doesn't explore the living lab concept that is being used under various regional names in different parts of the world. Accordingly, this research underscores the need for global, cross-regional studies that include non-European perspectives and explore similar "lab" models to enrich the understanding of living labs and identify ways to further their impacts. As such, cross-regional studies on the efficacy of living lab platforms in different regions and the governance attributes that such networks can usefully adopt would serve to strengthen living lab initiatives globally.

Future studies could apply the frameworks developed in this research to additional case studies to validate, refine, and extend their applicability and relevance. Conducting comparative case studies across diverse geographical and sociopolitical contexts could enhance the robustness, transferability, and relevance of both the learning framework and factors enabling policy influence. Furthermore, testing the learning framework is advocated across diverse domains and implementation phases to capture the heterogeneity of living lab practices and their evolving dynamics. Finally, there is the issue of lack of evaluation in living labs. Evaluation serves as a critical management tool and an integral component of research and innovation processes (Schaefer et al., 2021). There is a growing need to integrate both longitudinal and point-in-time evaluation approaches within living lab studies to capture the variability and complexity of living labs (Paskaleva & Cooper, 2021). Future investigations could consider developing and embedding mixed-method evaluation strategies to enable continuous learning, iterative improvement, and enhanced accountability within living lab ecosystems. Further, a post-experiment assessment conducted after a project ends could be beneficial for understanding long-term, broader impacts as well as potential weaknesses of the intervention. This is particularly important for projects involving nature-based solutions, as their effects emerge slowly, and often extend beyond the temporal and institutional boundaries of the project. As a network organization of living labs, ENoLL offers a potential vehicle for capturing such learning and enabling insights from post-experimental impact assessment to inform future initiatives through its involved community of researchers, member living labs, and innovation partners.

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A

SUPPLEMENTARY MATERIAL FOR CHAPTER 2

This has originally been published as supplementary material for paper; Bhatta, A., Vreugdenhil, H., & Slinger, J. (2023). Characterizing nature-based living labs from their seeds in the past. Environmental Development, 100959; also available at 4TU.ResearchData, DOI: 10.4121/f2fb5beb-2e36-45ef-9054-c7bd8712720c.v1

A.1. DESCRIPTION OF LIVING LAB CHARACTERISTICS FOR DATASET B

Living Labs	Primary LL characteristics	Description of characteristics
PHUSICOS (Lupp, Huang, et al., 2021; Lupp, Zingraff-Hamed, et al., 2021)	Real-life context and scale	Rural mountainous areas implementing NBSs to reduce the risk from natural hazards (Disaster risk reduction)
	Innovation and Learning	Development of NBS interventions and knowledge production
	User-centric (Co-creation)	• Stakeholders perceive the multi-benefits of NBS positively but are concerned about the effectiveness of NBS in aiding in problem mitigation, durability, and functionality. Therefore, PHUSICOS living lab develop strategies to involve stakeholders' needs and demands for a strong end-user focus; addresses the stakeholder's expectations of the living lab process and co-designing of NBS. • Living labs are used for the selection, co-design, implementation, monitoring & evaluation of its NBSs; the intense involvement and collaboration of the stakeholders is the core feature of the development process so that a strong sense of ownership for the overall process and mutually agreed measures is achieved.
	Participants	Authorities, foresters, tourism associations, commercial sectors, researchers and civil society
	Sustainability and Multiple Benefits	Address the hydro-meteorological hazards through the nature-based living lab using measures, such as re-establishment of floodplains, and farming practices that stabilize soil, while creating multiple benefits and values, such as enhancing biodiversity, creating habitats for endangered species & tourism improvement.
CLEVER Cities Project (Arlati et al., 2021; Mahmoud & Morello, 2021)	Real-life context and scale	Urban context with multiple scales at the city and neighborhood levels (ecosystem services, social innovation)
	Innovation and Learning	Nature-based interventions, such as green corridors, green roofs and façade, and green schoolyards; contribute to a certain degree of citizen empowerment and learning among the participants; explore and experiment solutions
	User-centric (Co-creation)	• Focus on a citizen-driven paradigm and adopt a user-centered design; highlight degrees of user engagement as; (i) citizens affected by the NBS but not engaging actively in the process, (ii) citizens affected by the NBS and participating in the process, and (iii) citizens affected by the NBS and engaging actively in the process and can influence the decision-making. • Implementation of NBSs following the co-creation logic called the co-creation pathways; includes co-creation planning, co-design, co-implementation, and co-development phases
	Participants	Quadruple helix network of stakeholders with multi-disciplinary knowledge and varying competencies, such as urban planning, policies, environmental technology, and socio-economic studies
	Sustainability & Benefits	Application of NBSs to achieve social co-benefits and environmental & economic improvements
	Openness & equal power	Briefly mentions clarity, transparency, and openness as central to the trust-building process
	Upscaling	project aims to scale up the learning from the living lab project at city level to the federal level

UnaLab (Chroneer et al., 2019; DeLosRíos-White et al., 2020; Rizzo et al., 2021)	Real-life context and scale	Urban context: develops a toolkit to identify relevant scales for the project
	Innovation and Learning	Aims for social innovation by exploring and supporting dialogues around innovation activities and engaging different stakeholders to work towards the project's aim of addressing climatic and environmental challenges
	User-centric (Co-creation)	• DeLosRíos-White et al. (2020) develops a co-creation tool for UnaLab that uses participatory and user-centered methods to design a framework for stakeholder engagement. • Highlights co-creation with stakeholders as an important part of their living labs; presents five stages of NBSs co-creation as co-explore, co-design, co-experiment, co-implement, and co-manage
	Participants: Multi-Actors	quadruple helix network of partners and stakeholders as end users, citizens, public and private sector and academic institutions, with additional specific internal and external roles
	Sustainability and Benefits	NBSs for sustainable development i.e., to bring nature back to the city; mitigate local climate problems.
URBiNAT (Nunes et al., 2021)	Real-life context and scale	in the context of inclusive urban regeneration within and between neighborhoods
	Innovation and Learning	Emphasize diversity and learning from social innovation as central to the living lab innovation outcomes
	User-centric (Co-creation)	• Encourages user-involvement using tools familiar to citizens, including digital tools along with face-to-face user engagement for increase cooperation likelihood. • Highlight citizen engagement and co-creation of NBS through a strategic participatory approach to tackle societal inequality and socio-economic disparities
	Participants: Multi-Actors	transdisciplinary multi-stakeholder participation that involves stakeholders such as residents, local authorities, community groups, companies, academics, and local communities
	Sustainability & Benefits	Improve urban sustainability and liveability while fostering inclusivity and social justice
	Openness & equal power	Briefly mentions clarity, transparency, and openness as central to the trust-building process.
Dublin City Greening (Clavin et al., 2021)	Real-life context and scale	inner-city of Dublin on a neighborhood scale
	Innovation and Learning	Environmental and social innovation, which ensures high social and cultural values, engagement between different stakeholders, and development of inclusive greening strategies
	User-centric (Co-creation)	• This case demonstrates a community-led greening strategy that is both inclusive and policy-relevant • Co-creation: where the data was opened up with communities and stakeholders for creative and supportive space for dialogue and plans for greening interventions, after scientifically mapping green space first
	Participants	scholars, activists, artists, other formal stakeholders, and residential communities
	Sustainability and Multiple Benefits	This greening intervention aims at urban resilience while responding to neighbourhood needs and maximizing opportunities for community well- being.

Sustainable Food Transition (Ribeiro & Lewis, 2021)	Real-life context and scale	In the context of urban food forestry
	Innovation and Learning	Exploring use of nodes for urban forestry network
	User-centric (Co-creation)	selects the participatory approach of co-creation by Mccormick and Hartmann (2017)
	Participants	Follow participatory approach involving various stakeholders
	Sustainability and Multiple Benefits	Enhance urban resilience by adding urban edible forestry as a strategic part of the metropolis' metabolism while enhancing biodiversity and ecological services.
Enhance Eco-system Services (García-Llorente et al., 2019)	Real-life context and scale	Agricultural landscapes in Madrid
	Innovation and Learning	Achieve collaborative learning between urban and rural communities and empower the participant
	User-centric (Co-creation)	co-design and co-production with all stakeholders according to their level of interest and competence; promotes dialogue through collaboration and experimental learning among participating stakeholders
	Participants	Academics, practitioners, activists, civil society
	Sustainability and Benefits	Enhanced eco-system services
	Openness and equal power	Highlights the openness feature of Agrolab, where people of multiple backgrounds were embraced to share knowledge and experiences and where the designs are open to innovative ideas

A.2. VOSVIEWER OUTPUT

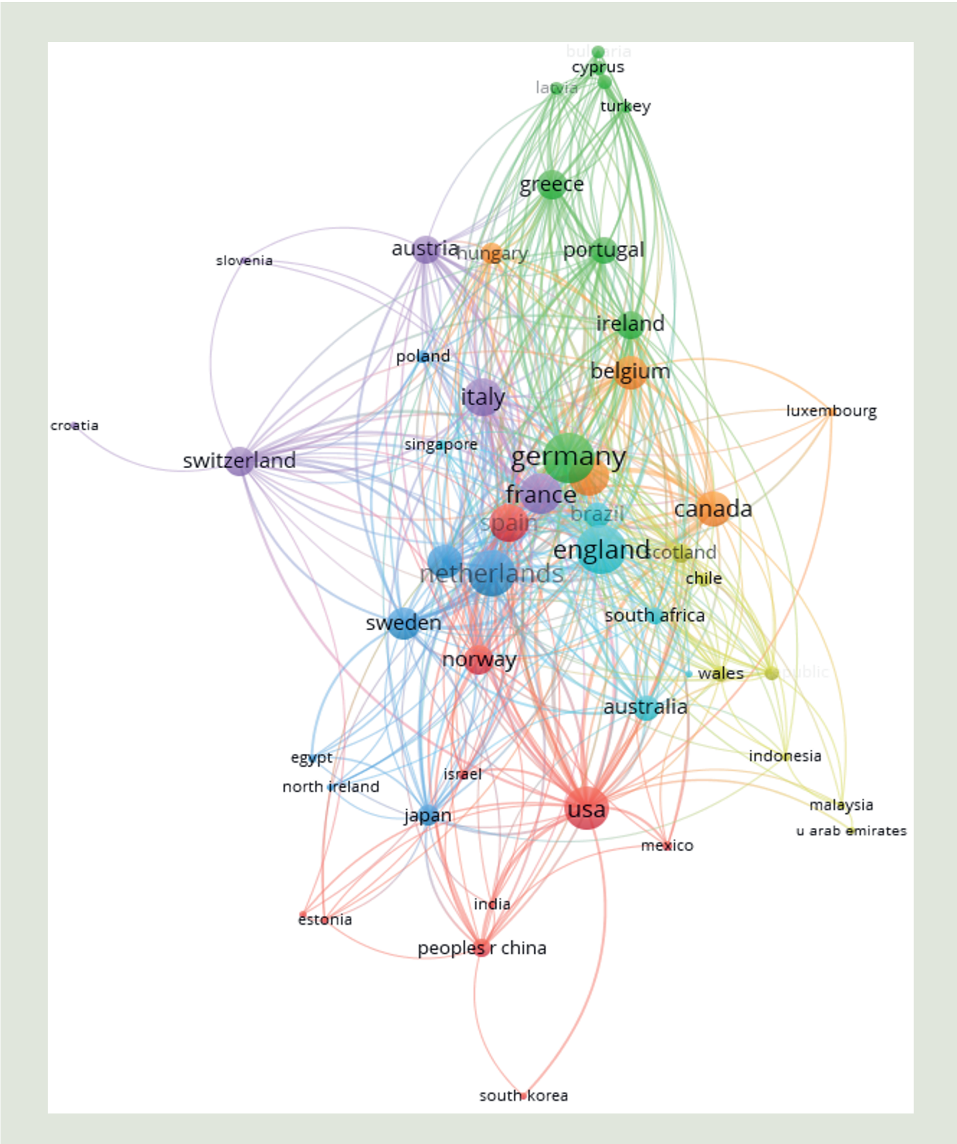
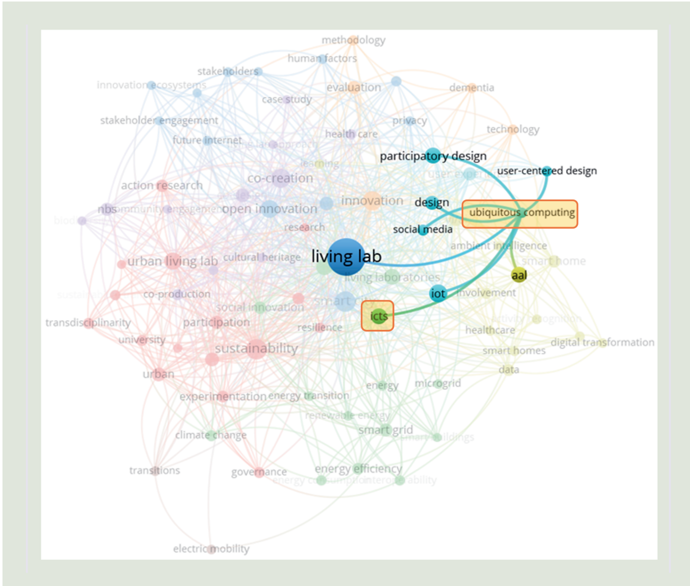
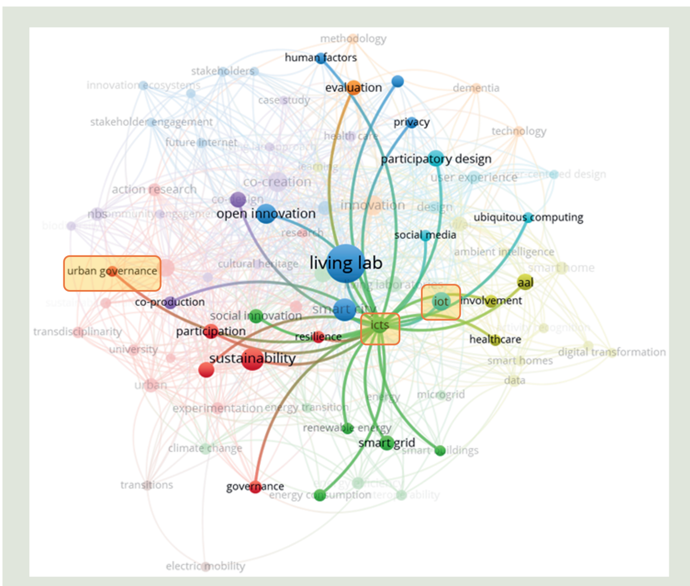


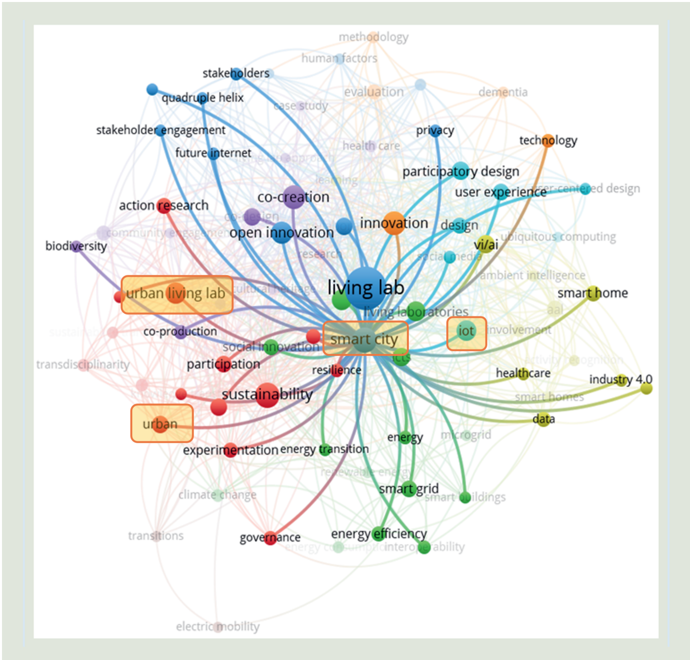
Figure A.1.: Bibliometric Coupling of living lab literature according to countries; r=5 (Orientation of figure A1.1 is landscape in the original publication; it is changed into portrait to fit the paper size of this dissertation)



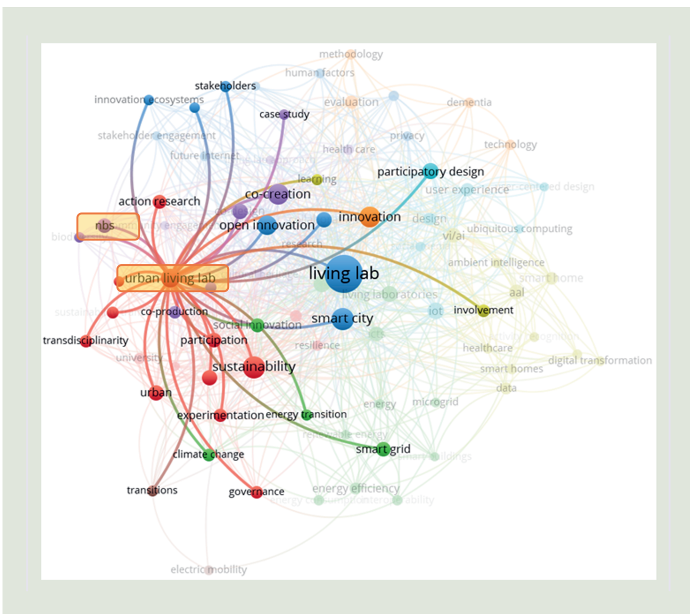
(a) “Ubiquitous computing” keyword (identified in 1st cluster of living lab timeline; figure 2.2) and its link to other keywords



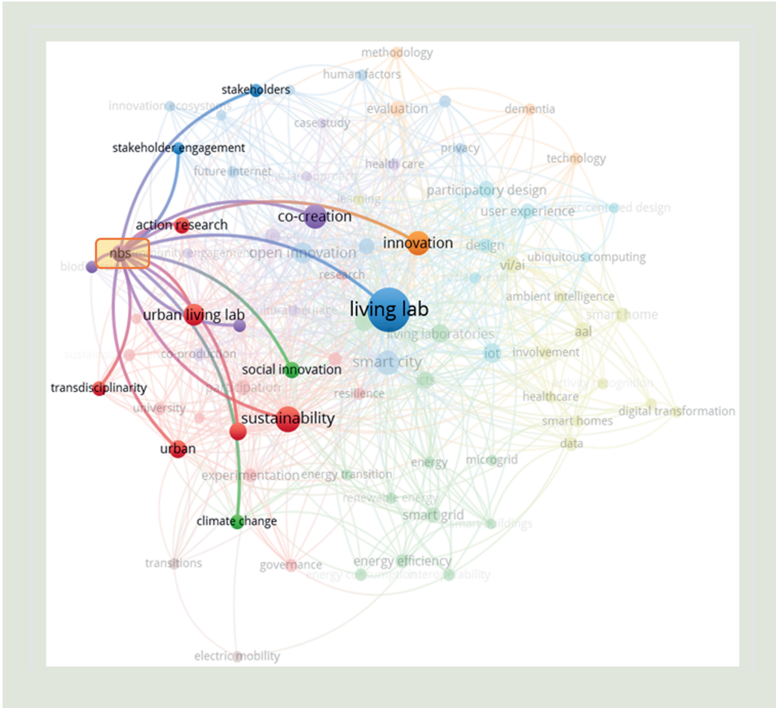
(b) Keyword “icts” links to keyword “smart city” through multiple paths, i.e., through urban governance, internet of things (iot), sustainability, etc.



(c) Keyword "icts" links to keyword "smart city" through multiple paths,i.e., through urban governance, internet of things (iot), sustainability, etc.



(d) Keyword "urban living lab" appears as one of the links from keyword "smart city"; keywords link of "urban living lab" is then examined.



(e) Keyword “nbs” is linked to keyword “urban living lab” (only visible in the cluster after 2019.

Figure A.2.: The links between living lab keywords are highlighted in Figures (a) to (e)

B
SUPPLEMENTARY MATERIAL FOR CHAPTER 3

This chapter has originally been published as; Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). A living lab learning framework rooted in learning theories. Environmental Impact Assessment Review, 114, 107894; also available at 4TU.ResearchData, DOI: 10.4121/cdeaa7b5-fa3e-432c-b046-1d6221afbe7d.v1

For transparency purposes, the literature selection and review process is detailed in the tables below.

- Table A, provides a full list of papers selected for each of the search terms
- Table B, indicates the number of papers per database
- Table C, provides a full list of all 287 papers with the relevant learning theories distinguished and which of them are operationalized, selected 180 papers are highlighted
- Table D, summarizes the frequency of occurrence of the learning theories identified in table C
- Table E, provides secondary examination of learning theories with frequency of occurrence less than ten (f < 10)
- Table F, lists the learning theories selected for this research
- Chart A, shows journals hosting the papers used for this research

The full analysis was carried out by the first author with the other authors independently reviewing the findings.

B.1. TABLE A: LIST OF SEARCH KEYWORDS USED IN SCOPUS AND WOS

	Keywords used for search in SCOPUS+WOS			No. of Papers	Repeated papers	Non-English papers	Paper not related to LT	Final selection
A	Real-life settings	+	Real-life context	**13**	1		3	9
B	Innovation	+	Doc: Review	**66**	1	1	11	53
C	User-centered	+	user-centric	**33**	0	1	8	24
D	Co-creative	+	co-creation	**33**	0	1	3	29
E	multi* stakeholders	+	Quadruple helix	**23**	0		7	16
F	Sustainable	+	Sustainability	**40**	0	1	9	30
G	Digitalization	+	Digital age	**79**	2		9	68
				287			*Papers selected for the study:*	229
							Papers repeated between A-G:	4
							Remaining papers considered:	**225**
							Total papers considered:	**180**

B.2. TABLE B: PAPERS IN TABLE A SUBDIVIDED INTO SCOPUS AND WOS DATABASE

	SCOPUS	WOS	TOTAL	
A	12	4	**13**	(1- repeated with Scopus)
B	43	33	**66**	(9- repeated with scopus) (1-repeated within WOS)
C	33	1	**33**	(1- repeated with Scopus)
D	33	0	**33**	
E	22	1	**23**	
F	32	22	**40**	(14- repeated with Scopus)
G	79	1	**79**	(1- repeated with Scopus)
			287	

B.3. TABLE C: LIST OF ALL PAPERS AND ALL LTS APPLIED AND OPERATIONALIZED IN THESE PAPERS

This section can be found in:
The Supplementary material of the paper "A living lab learning framework rooted in learning theories", AND 4TU.ResearchData,
DOI: 10.4121/cdeaa7b5-fa3e-432c-b046-1d6221afbe7d.v1

B.4. TABLE D: SUMMARY OF LEARNING THEORIES AND THEIR FREQUENCY

	Learning theories	Frequency	
1	*Social LT*	*34*	*Learning theories with frequency of occurrence equal to or more than ten (f≥ 10)*
2	*Experiential LT*	*32*	
3	*Connectivism LT*	*30*	
4	*Constructivism LT*	*28*	
5	*Organizational LT*	*28*	
6	*Adult LT*	*25*	
7	*Cognitivism LT*	*16*	
8	*IT-related LT*	*15*	
9	*Transformative LT*	*14*	
10	*Situated LT*	*13*	
11	*Behaviorism LT*	*10*	
12	Sociocultural LT	4	*Learning theories with frequency of occurrence less than ten (f < 10)*
13	Deep LT	4	
14	Problem-based	2	
15	Contemporary LT	2	
16	Language LT	1	
17	Posthuman learning theory	1	
18	Active LT	1	
19	Komboltz's happenstance learning theory	1	
20	Unifying modern learning theory	1	
21	immersive learning technology	1	
22	Mastery Learning theory	1	
23	Vocabulary learning theories	1	
24	Gordon's musical LT	1	
25	Statistical LT	1	
26	Ubiquitous learning based on unifying existing LT	1	
27	Mayer's multimedia LT	1	
28	Failure LT	1	
29	Expansive LT	1	
30	Multimodal LT	1	
31	Interorganizational LT	1	
32	Self-organisation and informal LT	1	
33	Transactional LT	1	
34	Entrepreneurial LT	1	
35	Self-regulated LT	1	
36	Gamified LT	1	
37	Observational LT	1	
38	Explicit LT	1	
39	Community-based LT	1	
40	Motor learning theory	1	

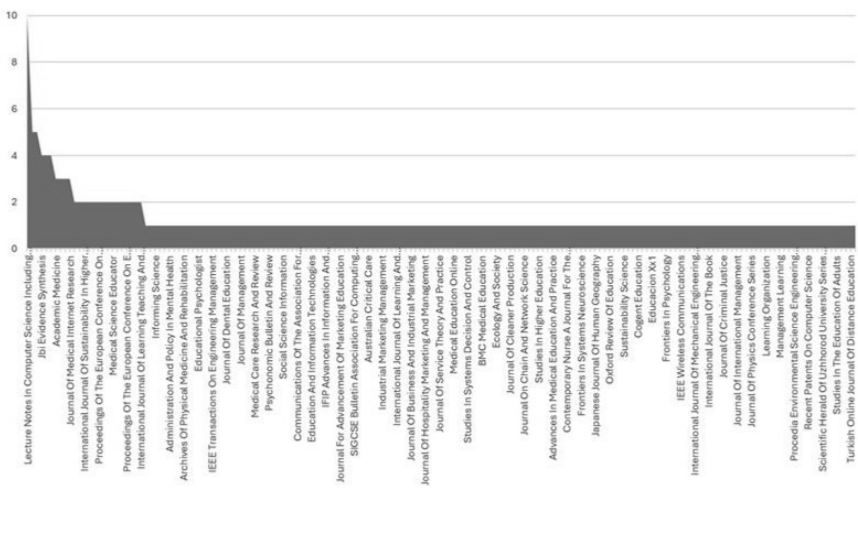
B.5. TABLE E: SECONDARY EXAMINATION OF LEARNING THEORIES FROM TABLE D FOR THEIR POTENTIAL INCLUSION IN THE STUDY

This section can be found in:
the Supplementary material of the paper "A living lab learning framework rooted in learning theories", AND 4TU.ResearchData,
DOI: 10.4121/cdeaa7b5-fa3e-432c-b046-1d6221afbe7d.v1

B.6. TABLE F: LIST OF SELECTED LEARNING THEORIES

Learning theories
Behaviorism learning theory
Cognitivism learning theory
Constructivism learning theory
Experiential learning theory
Situated learning theory
Social learning theory
Organizational learning theory
Transformative learning theory
Connectivism learning theory

B.7. CHART A: LIST OF JOURNALS HOSTING THE PAPERS USED FOR THIS RESEARCH



B.8. RELEVANT LEARNING THEORIES

1. Classic learning theory
   Behaviorism, cognitivism, and constructivism are recognized as three prominent classic learning theories (Harasim, 2017). Rooted in objectivism epistemology, Behaviorism views learning as external observable behavior changes of an individual (Conradie, 2014). There are two major types of behaviorism: methodological focusing on behavior change through structured rewards and feedback (stimulus-response) (Muhajirah, 2020), and radical focusing on changes through defined interaction with environmental stimuli, i.e., stimulus-response-reinforcement (Jung, 2019). Cognitivism, also rooted in objectivism epistemology, shifts the emphasis from learning as an external behavior to an internal mental process, where individual learners acquire knowledge by deliberately applying cognitive strategies, such as memory techniques and attention, to produce learned output behavior (Harasim, 2017; Jung, 2019; Muhajirah, 2020). Constructivism, rooted in constructivist epistemology, defines learning is an active knowledge-construction process rather than acquisition. Individual constructivists define learning as meaning construction based on personal experiences, whereas social constructivists define learning as a collaborative process (Harasim, 2017; Jung, 2019). However, since learning entails both objectivism and constructivism, the most realistic learning model lies in combining these positions (Jonassen, 1991). Contemporary learning theories build upon and extend classical theories to address the complexities of modern learning, and an increased understanding of the diverse ways people learn. In this paper, we go on to highlight experiential, situated, social, organizational, transformative, and connectivism learning theories from their basis in classic learning theories.

2. Experiential learning theory
   Experiential learning theory argues that knowledge is created through direct experience and reflection on that experience. Thus, it emphasizes the practical application of knowledge from the content and learner perspective, such that learners are viewed to be in charge of their own learning (Harvey et al., 2016; Kolb, 2007). It focuses on learning through purposeful individual experiences, reflections on how to apply this learning across disciplines, and less on social interactions (Quay, 2003). It integrates self-reflection on the learner's experiences in extracting unplanned learning and insights from real-life experiences (Halupa, 2015). The article by Kolb and Kolb (2013) helps individuals to "identify the way they learn from experience" by addressing four learning modes—experiencing, reflecting, thinking, and acting— repetitively. Experiential learning is also viewed as transactional as the relationship between experience and environment is reciprocal (Ord, 2012). This theory combines pragmatism, cognitivism, and constructivism (Quay, 2003) and the field of theory of learning epistemology (Kolb et al., 2014). Experiential learning theory perceives learning as a process rather than conceptualizing it in terms of

outcomes (Masethe et al., 2017). In relation to living labs, experiential learning theory embraces self-directed learning within individuals and teams and thus, follows the andragogy philosophy that forms the base for adult learning.

3. Situated learning theory
   Situated learning theory emphasizes learning within specific contexts, where knowledge, skills, and tactics are co-constructed among peers through active engagement in real-world situations, social interactions, and negotiations (Curnow, 2022; Lave & Wenger, 1991). The proponents of this theory argue that learning is not simply the reception of facts and cannot be decoupled from practice and people interacting in and between multiple contexts (Lave & Wenger, 1991; Tyre & Von Hippel, 1997). Situated learning theory legitimizes peripheral participation, i.e., where new learners move gradually from peripheral participation towards full participation within the community of practice (COP) as they get more involved (Lave & Wenger, 1991; Light, 2006). Thus, learning is not just "knowing" but also "a way of being" in the social world, (Figure B.2) (Light, 2006). Therefore, situated learning theory shifts away from a solely epistemological account of an individual (cognitive activity) and regards learning as a process of participation in communities of practice and has a deep-rooted affinity with social constructivism (Lave & Wenger, 1991; Quay, 2003; Willett, 2007) and pragmatism (Tyre & Von Hippel, 1997). In combination with adult learning, situated learning theory enables learners to independently create knowledge through relationships with other participants, engagement in activities, and the social context, informed by their prior life experiences (Eddy et al., 2019).

   Situated learning theory is inseparable from social learning due to the significance of social context in both theories (Light, 2006). However, situated learning theory emphasizes active participation and engagement, where learning occurs through doing, collaborating, and participating in the social context and suggests that learning is not in an individual mind; instead, it takes place within a participation framework (Lave & Wenger, 1991). In contrast, social learning theory focuses on observation and imitation, where learning happens by observing behaviors and outcomes of others' actions within a social context (Rigg & O'Dwyer, 2012).

4. Social learning theory
   Social learning theory centers around the idea that knowledge is constructed socially as a byproduct of shared experiences (Vygotsky & Cole, 1978). Early work conceptualizes social learning as individual learning influenced by imitating other's behaviors and attitudes in a social context rooted in behaviorism (Jonassen, 1991), which was shifted towards the cognitive process involved in observation (Gibson, 2004). The recent literature on social learning theory emphasizes the role of social aspects in two ways (Rigg & O'Dwyer, 2012). The first approach defines learning as observations, interactions, and communication within social situations (Conradie, 2014), and the second

argues that social and cultural values and practices play a key role in fostering learning within a group by sharing common environmental and experiential factors through, for example, "Community of Practice" (Bruner, 1996; Rannikmäe et al., 2020). Glucker et al. (2013), Sinclair et al. (2008), and O'Faircheallaigh (2010) forward collective social learning as an enabler to desired sustainability transition at broader level. This theory points out that learning involves not only conscious but also non-conscious perceptions and understandings, embodied through taking part in social life (Light, 2006). Rooted in social constructivism epistemology, it proposes that new ideas are created, and new meanings are derived only through engaging in dialogue with others (Ernst, 2019; Reed et al., 2010; Rigg & O'Dwyer, 2012). Thus, social learning is a change in understanding (either surficial or deeper) through social interaction within a social network such that the change of understanding goes beyond the individual or small group to become situated within a wider social unit (Reed et al., 2010). Social learning theory can be utilized to understand the interactions among the individual stakeholders in living labs.

5. Organizational learning theory
Organizational learning theory focuses on how organizations acquire, create, retain, and transfer knowledge, especially when addressing complex, "wicked" problems (Argote, 2012; Crossan et al., 1999; Kringelum & Brix, 2020). Although understanding of organizational learning began with the application of cognitive learning, where an organization was viewed as a system of interrelated roles, and therefore, its learning equated, primarily, to the sum of learning of individuals in the roles (Dutta & Crossan, 2005), research has demonstrated that collective learning can surpass the sum of individual learning (Argyris & Schön, 1996; Reed et al., 2010). Additionally, organizational learning is recognized as "situated" within the learning activities of individuals, teams, and (inter) organizational networks (Dutta & Crossan, 2005). Crossan et al. (1999) identify organizational learning as multilevel, where different processes link the individual to that of the group and the organization.

   Organizational learning is not restricted to merely acquiring new knowledge; instead, this knowledge is applied within the organization, thus carries the notion of "learning by knowing" (Figure B.2) (Hong & Easterby-Smith, 2002). Organizational learning may be used as an innovative strategy for managing change and addressing uncertainties (O'Sullivan, 1999). The organizational learning process is often systematized through the concept of single-loop, double-loop, and triple-loop learning, as shown in Figure B.1 (Argyris & Schön, 1996; Pahl-Wostl, 2015). This perspective recognizes both the positivist (or cognitive) and constructivist (situated) side of learning, i.e., learning is "socially constructed" and grounded in the cognitive and behavioral capacity of individuals (Bell et al., 2002; Dutta & Crossan, 2005).

   Given that many living labs adopt a long-term organizational approach to societal transformation (Backhaus et al., 2023; Schuurman, 2015), organizational learning theory is prominently reflected in these living lab organizations.

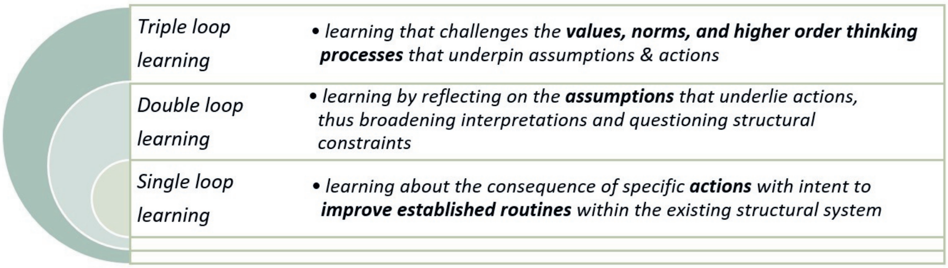


Figure B.1.: Single, Double, and Triple loop learning in organizational learning theory

6. Transformative learning theory
   Transformative learning theory offers a framework for understanding how individuals shift their perspectives, beliefs, and actions through critical reflection on their assumptions and biases (Mezirow, 1993, 2018). This theory suggests that learning can occur through expanding and refining the present knowledge system, acquiring a new set of learning skills (instrumental); understanding and reinterpreting knowledge through communication (communicative); being aware of one's own biases or assumptions; and transforming them through reorganizing meaning and perspectives (transformative) (Kitchenham, 2008; Mezirow, 2018; Simsek, 2012). It can be viewed as a social andragogy where learners reflect on previous knowledge and experiences (Halupa, 2015). Transformative learning is also shaped by collaborative and deliberative social learning (Lotz-Sisitka et al., 2015). Transformative learning theory, founded by Mezirow (1993), builds heavily on constructivism and pragmatism epistemology (Laros et al., 2017) and centers around individuals leading to broader change. A wider societal transformation is required to create the desired sustainable transition that some living labs aspire to achieve (Gamache et al., 2020). The collective approach towards transition through the social transformation of local communities highlights the possible role of living labs in supporting sustainable transition pathways.

7. Connectivsm learning theory
   In recent times, connectivism learning theory has emerged in response to the features of the digital age (Faiella, 2013; Masethe et al., 2017). Unlike most of the learning theories that place learning at the center of the cognitive development of an individual learner, connectivism defines learning as connections to a network of knowledge, both digital and non-digital (Hendricks, 2019; Masethe et al., 2017). The essence of connectivism lies in the idea that learning occurs through connections and networks with other individuals, information, resources, and technologies. Consolidated by behaviorism, cognitivism, and constructivism, connectivism learning theory is a paradigm shift from traditional learning theories to new ways of self-regulated learning through networks (connected people) and databases on different

e-learning platforms (Hendricks, 2019). Since its introduction in 2004, a body of literature offering criticism as well as expanding on applications of connectivism has developed (Downes, 2019), with one of the severest criticisms being that connectivism doesn't meet the criteria to be considered a learning theory (Clarà & Barberà, 2014; Kop & Hill, 2008). Indeed, other critics argue that human learning has always shaped and been shaped by the technology of time (Harasim, 2017). Given the lack of consensus that connectivism can be considered a learning theory, it is not depicted in Figure B.2.

B.9. SYNTHESIS OF LEARNING THEORIES

As outlined in section B.8, the literature on learning theories reveals their underlying philosophical differences between them, but in practice, a mix of learning theories is often used (Buzzetto-More, 2007; Carman, 2002). Many scholars stress the importance of combining multiple learning theories and philosophical perspectives. For instance, Jonassen (1991) and Sabri (2017) propose blending constructivism with objectivism into a new paradigm; while Kamel-ElSayed and Loftus (2018) and Van der Horst and Staddon (2018) emphasize combining various learning theories. Further, Carman (2002) establishes that there is a growing agreement that no single learning theory is the best, and a unified learning theory may never exist; instead, an appropriate blend of learning theories may be applied based on the context. Despite their distinct approaches, learning theories outlined in section B.8 exhibit certain shared elements (Merriam & Caffarella, 1991), as illustrated in Figure B.2. Therefore, linking these modern theories allows for understanding of their unique and interconnected aspects enabling one to offset individual limitations by drawing on their respective strengths (Dangwal, 2017; Sabri, 2017).

The full list of references to section B.8 and B.9 can be found in:
The Supplementary material of the paper "A living lab learning framework rooted in learning theories", AND 4TU.ResearchData,
DOI: 10.4121/cdeaa7b5-fa3e-432c-b046-1d6221afbe7d.v1

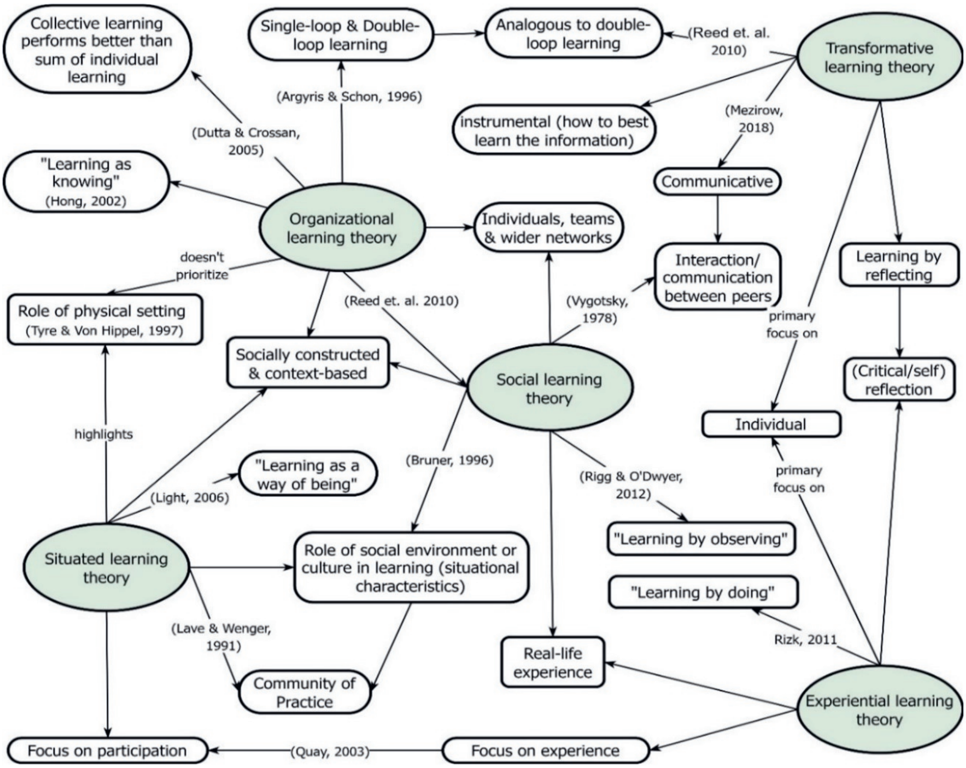


Figure B.2.: Possible links between contemporary learning theories (experiential, situated, social, organizational and transformative

C
SUPPLEMENTARY MATERIAL FOR CHAPTER 4

This chapter has originally been published as; Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). Harvesting living labs outcomes through learning pathways. Current Research in Environmental Sustainability, 9, 100277; also available at 4TU.ResearchData, *DOI: 10.4121/cdeaa7b5-fa3e-432c-b046-1d6221afbe7d.v1*

C.1. POTENTIAL COMBINATIONS THAT MAKE UP LEARNING PATHWAYS

In distinguishing learning pathways using the components of the Living Lab Analytical Framework (Figure 3.4), we turn to set theory, as visualized in Figure C.1. The learning processes (component "A") has two elements (n(A) = 2), namely: intentional and incidental learning. The learning types (component "B") and the learning levels (component "C") each have three elements (n(B) = n(C) = 3). Thus, theoretically, there are $2^{(n-1)}$ unique, non-empty sets of potential combinations of elements of each of the learning components. This means that learning process can have three unique combinations, as: $2^{(n(A)-1)} = 3$; while learning type can have seven: $2^{(n(B)-1)} = 7$; and learning levels can also have seven: $2^{(n(C)-1)} = 7$. For a specific unit of analysis, an activity in our case, the elements of the learning types (content, capacity and network) are not mutually exclusive, and can occur separately or together. Similarly, within a specific activity, learning can occur as intended, incidentally or both. Therefore, intentional and incidental learning process are also not mutually exclusive. Likewise, for the learning level, learning can occur at one, two of all three levels simultaneously. The learning pathways associated with project activities and their outcomes therefore comprise practically relevant, non-empty combinations of elements (i.e. sets) of each of the components of the Living Lab Analytical Framework, namely: learning processes, learning types and learning levels.

The number of pathways, therefore, concerns permutations without repetition with only one element selected at a time (r=1), theoretically yielding 147 potential learning pathways:

$$\frac{(2^{n(A)}-1)!}{(2^{n(A)}-1-r)!} \times \frac{(2^{n(B)}-1)!}{(2^{n(B)}-1-r)!} \times \frac{(2^{n(C)}-1)!}{(2^{n(C)}-1-r)!}$$

$$= \frac{(2^2-1)!}{(2^2-1-r)!} \times \frac{(2^3-1)!}{(2^3-1-r)!} \times \frac{(2^3-1)!}{(2^3-1-r)!}$$

$$= \frac{3!}{2!} \times \frac{7!}{6!} \times \frac{7!}{6!} = 3 \times 7 \times 7 = 147$$

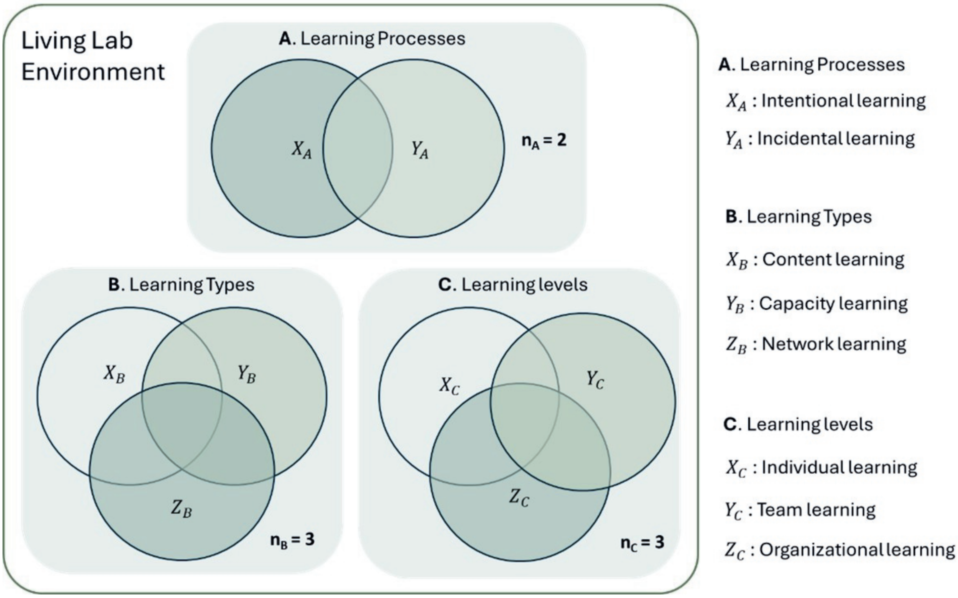


Figure C.1.: Visualizing the potential combinations of elements from the learning components that can make up learning pathways for a specific activity and outcome.

C.2. INTERVIEW AND SURVEY - PERSONNEL

As this study involved human subjects, the authors developed a data management and human ethics review plan in accordance with the requirements of the Delft University of Technology, as approved by the Human Research Ethics Committee under application number 106178. For the survey, no personally identifiable information was collected, thus, a consent form was not required. However, for interviews, informed consent was obtained from all interview participants prior to the data collection, in line with these protocols. Participants were informed about the purpose of data collection and assured that their data would be anonymized and processed confidentially. Participation was entirely voluntary, and participants had the opportunity to ask any questions or withdraw their data at any time.

A. Personnel interviewed (N=12):

		No. of personnel **(N=12)**
Public organization	Water authority	3
	Provinces	1
Research	University	4
	Other research institutes	2
Private	Private	1
Farmer organization	Farmer organization	1

B. Survey in the Final Symposium (N=26):

	No. of personnel	
	Within KLIMAP **(N=14):**	Outside KLIMAP **(N=12):**
Public organization	3	4
Research (University+ institutes)	9	8
Private	1	0
Farmer organization	1	0

C. Participation in workshops:

i) Co-creative and brainstorming sessions on-site (N=3)

Stakeholder meeting with Dialogue session Farm of the future *(Stakeholderbijeenkomst met dialoog sessies Boerderij van de toekomst)*	Wednesday 18 May 2022
KLIMAP roadshow Aa-dal Noord (Vitale Peel)	Wednesday 13 December 2023
Collaborating in IJssel Vallei: En route to the most beautiful valley of the Netherlands- *Samenwerken in de IJsselvallei: Op weg naar de mooiste vallei van Nederland!*	Wednesday 24 January 2024

ii) Community of practice (COP) meetings (N=2)

COP-2 KLIMAP-CASTOR (Interviewing agricultural entrepreneur)	Monday 11 April 2022
COP Castor/KLIMAP – Governance and spatial choices *(Governance en ruimtelijke keuzes)*	Thursday 16 February 2023

iii) Final project symposium (N=1)

End Symposium Project KLIMAP- Climate adaptation in the practice *(Eindsymposium project KLIMAP – Klimaatadaptatie in de praktijk)*	Thursday 21 March 2024

C.3. SURVEY QUESTIONS (TRANSLATED IN ENGLISH)

1. Name of your organization: ....

2. In what role did you represent in the **KLIMAP** project:

Not directly involved	Public sector	Private sector	Research organization	Civil society	Others

3. To what extent did the following knowledge processes take place during KLIMAP?

	Greatly	Somewhat	Very little	Not at all	No comments
Sharing existing knowledge					
Creation of new knowledge					
Development of new skills					
Understanding the work of other organizations					
Formation of new networks					
(Something else...)					

4. How do you rate the knowledge you personally acquired during KLIMAP?

Excellent	Above average	Average	Below average	Poor
Comments:				

5. How do you rate the knowledge developed during the KLIMAP project for your team/work package level?

Excellent	Above average	Average	Below average	Poor
Comments:				

6. How useful is the knowledge developed during the KLIMAP project for your organization?

Extremely useful	Above average	Mildly Useful	Below average	Not useful
Comments:				

7. How useful did you find the following knowledge activities during the KLIMAP project?

	Very useful	Useful	Not useful	Not applicable
Presentations				
Learning sessions				
Field Visits				
Workshops				
Brainstorming sessions				
Group discussions				
Serious games				
Case studies				
Social gatherings				
Others				

8. Please give your opinion on the following sentences based on your KLIMAP experiences.

	Yes	A bit	No	N.A.
I understand more about climate adaptation				
I have learned from practical experiences				
I have learned from other people and parties in KLIMAP				
I now understand the perspective of another discipline/stakeholder better				
I can use the acquired knowledge for other projects or situations				
I will use the knowledge in my organization				
I have become more aware of my underlying assumptions				
Others				

C.4. INTERVIEW PROTOCOLS

1. Opening
    a. Personal introduction exchange
    b. Focus of research and purpose of the interview
    c. Interview outline- semi-structured interview
    d. Permission to record the interview for internal use only
    e. Highlighting interviewee's anonymity and right to withdraw
2. Confirm participation
    a. Confirm proceeding
    b. Review consent form
3. Interview questions
    a. Open questions
    b. Checklist to confirm all topics are covered
4. Closing
    a. End of interview, thanking for time and sharing views
    b. Ask if interviewee have any questions or points for discussions
    c. Agree on if interviewee want to be in the follow-up loop

C.5. INTERVIEW QUESTIONS

1. Personal introductory questions
    a. Profession & expertise
    b. Role in KLIMAP and the reason for involvement
    c. Since when are you involved in KLIMAP
2. Project introductory questions:
    a. What is the idea behind KLIMAP? How was it initiated?
    b. What did KLIMAP wanted to achieve (goal)? And core problem addressed?
    c. Who was involved and in what capacity? How diverse are the actors? What does a typical stakeholder group look like?
    d. How do you select the members who participate?
    e. Why did the project aim for this format of stakeholder involvement?
    f. How is KLIMAP organized, in terms of working themes?
3. What can you tell me about the case studies?
    a. No. of case studies /fieldsites

   b. Actors involved in each case study and diversity within the group
   c. Goal of each case study
   d. How were the Case studies organized; resource allocated?
   e. Activities that took place in each case study and how often?
   f. Tools and methods applied
   g. Main output and outcomes

4. What can you tell me about the field experimentation?
   a. Type of field experiments
   b. How were the experiments organized, selected?
   c. Experiment locations, activities, tools and methods applied
   d. Who were involved in which experiment?
   e. Output from the experiments
5. What activities are you involved with in the project outside case study and experiments?
6. What are "learning sessions"? How often is it hosted? Who gets invited? Who participates? what is the topic of discussion? And what is the aim of these sessions?
7. How did you organize the information flow within such big group?
8. Has any stakeholder left the project or joined the project at later stage? How did you make sure that all stakeholders are actively engaged?
9. What can you tell about the relationship and interactions between involved stakeholders/ organizations? Regarding collaboration, resource sharing, trust and conflicts?
10. Was there any expertise missing? If yes, what?
11. Do you perform a regular monitoring and evaluation?
    a. If yes, what do you do with the results?
    b. If no, do you plan to do it in future?
12. Value and benefit of KLIMAP activities:
    a. to the stakeholders involved
    b. in achieving climate resilient goals
13. At personal level:
    a. What knowledge, skills and network perspective did you gain from KLIMAP?

   b. Have you used the knowledge and skills from KLIMAP in other projects or in partnership? If yes, where and how?

14. At team's level:
    a. How has your team's capacity changed over time during KLIMAP?
    b. Have you re-used or exchanged knowledge with other teams within or outside KLIMAP?

15. At organizational level:
    a. How has KLIMAP as the project evolved over time?
    b. What knowledge (regarding climate adaptation measures, perspectives of other stakeholders, etc.) from KLIMAP is useful for your organization?

16. Was there any unexpected result that surprised you?

17. After over 3 years of the project, what do you think really worked and what didn't?

18. What is the best aspect of KLIMAP, according to you?

D

SUPPLEMENTARY MATERIAL FOR CHAPTER 5

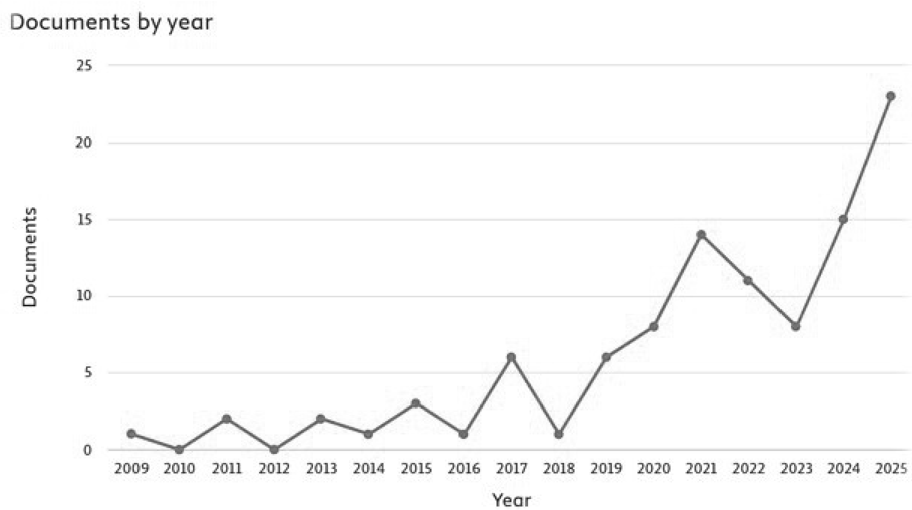
This chapter is submitted as: Bhatta, A., Vreugdenhil, H., Ellen, G., Schuurman, D., Slinger, J. (2026). Influence of living labs in the policy landscape

D.1. LITERATURE REVIEW:

D.1.1. TABLE A: INCLUSION/ EXCLUSION RATIONALE FOR LITERATURE REVIEW OF POLICY-RELATED LIVING LABS

Table A lists 111 papers resulting from the literature review. For each paper, its respective position within the policy process is identified, and the rationale for the inclusion and exclusion of each literature is mentioned.
This section can be found in:
the Supplementary Material of the paper "Influence of living labs in the policy landscape", AND 4TU.ResearchData,
DOI: 10.4121/cbd8f3b0-a440-48fd-8e1b-6f573a38eaba.v1

D.1.2. TREND OF POLICY-RELATED LIVING LAB LITERATURE (TABLE A) PUBLICATIONS BY YEAR, UNTIL 2025



D.2. CASE STUDIES:

D.2.1. PERSONNEL INTERVIEWED

	Name of the project	No. of personnel **(N=12)**
A.	Werken met Waterlandschappen (WmW)	4
B.	Climate Adaptation in Practice (KLIMAP)	3
C.	Self-Supporting River Systems (SSRS)	2
D.	Schouwen-Duiveland living lab (SDLL)	3

D.2.2. INTERVIEW PROTOCOLS

Same as Appendix C.4.

D.2.3. INTERVIEW QUESTIONS

1. Personal introductory questions
2. How were these projects designed?
    a. Goal of the living lab project
    b. Stakeholders involved
    c. Duration and location of the project
    d. Source of funding
3. What activities were implemented?
    a. Different types of activities
    b. Who were involved and in what capacity?
    c. How was the living lab process managed?
4. To what extent to which the goals were achieved?
    a. What were the end products? How did you deliver them?
    b. What were the factors that lead to project success?
    c. What were the lessons learnt?
5. Whether the projects influenced policy, in what ways?
    a. What were the policy influences of the project?
    b. In what way did the project align to policies?
    c. Enablers and barriers for policy influence

E

Data Management Plan

As this study involved human subjects, the authors developed a data management and human ethics review plan in accordance with the requirements of the Delft University of Technology, as approved by the Human Research Ethics Committee under application number 106178, where all personally identifiable information (PII) was anonymized and processed confidentially.

E.1. APPROVAL EMAIL: HUMAN RESEARCH AND ETHICS COMMITTEE

Date 18-Oct-2022
Contact person Dr. Cath Cotton, Policy Advisor Academic Integrity
E-mail c.m.cotton@tudelft.nl

TU Delft Delft University of Technology

Human Research Ethics Committee
TU Delft
(http://hrec.tudelft.nl/)
Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft
Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Living Labs: Outcome Mapping and Learning
Applicant: Bhatta, Astha

Dear Astha Bhatta,

It is a pleasure to inform you that your application mentioned above has been approved.

Thanks very much for your submission to the HREC which has been approved. We do additionally note/advise the following:

- Please specify the COVID-19 risks and measures taken to mitigate these risks in the IC form.
- We advise a precautionary approach on the publication of interview transcripts: in principle we advise not to publish transcripts or provide access to them as raw data (other than to eg: examination boards). If it is necessary to do so particular care must be taken to make sure that transcripts are not only "anonymous", but not identifiable. Where it is felt that transcripts or transcript summaries must be published, we advise that where possible the transcript/summary itself should be approved by participants or else it is confirmed by the TU Delft Privacy Team that this is not necessary.

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

E.2. INFORMED CONSENT FORM

Delft University of Technology
INFORMED CONSENT- INTERVIEW

You are being invited to participate in the interview conducted for PhD research study titled 'Living Labs: Outcome Mapping and Learning.' This study is being done by Astha Bhatta, PhD researcher from the TU Delft, under the funding of the NWO CASTOR project, file number: NWA.1292.19.362.

The purpose of this study is to strengthen the learning (environment) of Living Labs and enhance their contributions to landscape and water management adaptation practice while pursuing nature-based approaches. The data will be used:

- To understand the characteristics of living labs that pursue nature-based solutions, and
- To assess the learning and impact of the living labs.

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
A: GENERAL AGREEMENT – RESEARCH GOALS, PARTICPANT TASKS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the study information above or it has been read to me. I have been able to ask questions about the study and my questions have been answered to my satisfaction.	☐	☐
2. I consent voluntarily to be a participant in this study and understand that I can refuse to answer questions and I can withdraw from the study at any time by emailing Astha Bhatta at a.bhatta-1@tudelft.nl, without having to give a reason.	☐	☐
3. I understand that taking part in the study involves: Audio or video recorded during the interview are stored on TUDelft institutional storage during the research that is accessible to the research team only. The recordings will be permanently destroyed as soon as the supporting publication is published.	☐	☐
4. I understand that the study will end by 15/02/2026.	☐	☐
B: POTENTIAL RISKS OF PARTICIPATING (INCLUDING DATA PROTECTION)		
5. I understand that taking part in the study also involves collecting specific personally identifiable information (PII) (name and email address, and audio recording) and associated personally identifiable research data (PIRD) with the potential risk of my identity being revealed, which will be mitigated by keeping the data in TUD institutional storage.	☐	☐
6. I understand that the following steps will be taken to minimise the threat of a data breach, and protect my identity in the event of such a breach: • The raw data will be stored in the TUDelft provided institutional storage with access to the research team only. Only the anonymized data needed to support the publications will be made openly available through 4TU.ResearchData.	☐	☐
7. I understand that personal information collected about me that can identify me, such as the name of the participant and the name of the organizations that participants represent, <u>will not be shared beyond the study team.</u>	☐	☐

PLEASE TICK THE APPROPRIATE BOXES	Yes	No
8. I understand that my contact information and this consent document will be preserved for the duration of the project but will be destroyed, after the study period, definitely before 15/02/2026.	☐	☐
C: RESEARCH PUBLICATION, DISSEMINATION AND APPLICATION		
9. I understand that after the research study the de-identified information I provide will be used for reports, publications and websites.	☐	☐
10. I understand a technical summary of the interview, needed to support the publications, will be made openly available through 4TU.ResearchData.	☐	☐
11. I agree that my responses, views or other input can be quoted anonymously in research outputs.	☐	☐
12. I give permission to be invited to review my interview summary before publication.	☐	☐
D: (LONGTERM) DATA STORAGE, ACCESS AND REUSE		
13. I give permission for the de-identified (anonymized) interview summary that I provide to be archived in the 4TU data repository, and will be publicly accessible so it can be used for future research and learning.	☐	☐

Signatures

________________ ________________ ________________

Name of participant Signature Date

I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.

________________ ________________ ________________

Researcher name Signature Date

Study contact details for further information: *Astha Bhatta, A.bhatta-1@tudelft.nl*

AUTHOR'S BIOGRAPHY

Astha Bhatta was born and raised in Kathmandu, the capital city of Nepal. She obtained her bachelor's degree in Civil Engineering from Tribhuvan University in Nepal. Following her graduation, she worked as a civil engineer in earthquake-affected regions of Nepal within the Department of Urban Development and Building Construction. In 2018, she moved from Nepal, home to the world's tallest mountains, to the Netherlands, one of the lowest-lying countries, to pursue a master's degree in urban environmental management at Wageningen University. Her master's thesis focused on developing a decision Support System for the selection of alternative water sources in the industrial zones of urban delta regions. She completed her internship in Ephyra sludge technology at Royal HaskoningDHV. After completing her master's degree in 2020, she joined Wageningen University as a researcher within the Urbanizing the Deltas of the World project. In 2022, Astha began her PhD journey at the Faculty of Technology, Policy and Management of Delft University. During her PhD, she researched living labs in land and water management, their learning outcomes, and policy influence, the results of which are reported in this dissertation.

PUBLICATIONS

PUBLISHED AND PART OF THIS THESIS

- Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). Harvesting living labs outcomes through learning pathways. Current Research in Environmental Sustainability, 9, 100277.

- Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). A living lab learning framework rooted in learning theories. Environmental Impact Assessment Review, 114, 107894.

- Bhatta, A., Vreugdenhil, H., & Slinger, J. (2024). Characterizing nature-based living labs from their seeds in the past. Environmental Development, 49, 100959.

SUBMITTED AND PART OF THIS THESIS

- Bhatta, A., Vreugdenhil, H., Ellen, G., Schuurman, D., & Slinger, J. (2026). Influence of living labs in the policy landscape

OTHER PUBLICATIONS

- Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). Kunnen living labs bijdragen aan innovatief waterbeheer in Nederland? Water Governance 12/2025, STOWA, ISSN 2211-0224.

- Bhatta, B., Singh, U., Adhikari, B. R., Karki, S., & Bhatta, A. (2025). Tracing Morphological Transformations and Braiding Dynamics in the Himalayan Rivers of Nepal. Remote Sensing Applications: Society and Environment, 101705.

- Bhatta, A., Le, T. M., Wetser, K., Kujawa-Roeleveld, K., & Rijnaarts, H. H. (2023). Stakeholder- based decision support model for selection of alternative water sources-a path towards sustainable industrial future in vietnam. Journal of Cleaner Production,385, 135539.

CONFERENCE PRESENTATIONS

- NCR days 2022- Delft, the Netherlands (Oral Presentation)
  Bhatta, A., Vreugdenhil, H. S. I., & Slinger, J. (2022). Living labs for improved collaboration in river management. In NCR DAYS 2022: Anthropogenic Rivers (pp. 97-98).

- ECCA 2023- Online (Poster Presentation)

- Open living lab Days 2023- Barcelona, Spain (Oral Presentation)
  Bhatta, A., Vreugdenhil, H., & Slinger, J. (2023). Building a living lab learning framework: Understanding the types, processes, levels and outcomes of learning in living labs. Proceedings of the Open Living Lab Days Research Day Conference Proceedings, Barcelona, Spain, 226.

- Landscape 2024- Berlin, Germany (Oral Paper Presentation)
  Bhatta, A., Vreugdenhil, H. S. I., & Slinger, J. (2024). Exploring learning within living labs to improve their impact on policy sphere. In Landscape 2024: Agroecosystems in Transformation: Visions, Technologies, and Actors (p. 168). Leibniz Centre for Agricultural Landscape Research (ZALF).

- Open living lab Days 2024- Timisuara, Romania (Oral Paper Presentation)
  Bhatta, A., Vreudenhil, H., & Slinger, J. (2024). How can living labs contribute to policymaking?. Proceedings of the Open Living Lab Days Conference 2024 (p. 368).

- NAC 2025- Noordwijk, the Netherlands (Oral Presentation)

- ISPIM 2025- Bergen, Norway (Oral Presentation)

- Open living lab days 2025- Andorra City, Andorra (Session + Oral Paper Presentation) *Bhatta, A., Vreugdenhil, H. S. I., & Slinger, J. (2024). Evaluating Living Labs' role in policy domain. Proceedings of the Open Living Lab Days*

Conference 2025- Living Labs for Regenerative Futures: Connecting local and global innovation ecosystems (p. 86).

- Adaptation Futures 2025- Christchurch, New Zealand (Oral Presentation)
- Session at MADA, Monash University- Melbourne, Australia (Oral Presentation)

About the Dissertation

Sustainable land and water management requires integrated strategies that combine technical, ecological, and socio-economic dimensions, through cross-disciplinary and cross-sectoral collaboration among diverse stakeholders, including farmers, ecologists, hydrologists, planners, policymakers, and business owners. Within this context, the dissertation explores the role of "living labs" as innovative, co-creative approaches, using the metaphor of plant cultivation. This research advances understanding of living labs by exploring their seeds in the past to their roots in learning, their harvest as learning outcomes, and their influence on the policy landscape through Dutch case studies, particularly in climate-adaptive land and water management.

About the author

Astha Bhatta holds an MSc in Urban Environmental Management from Wageningen University, the Netherlands, and a Bachelor's Degree in Civil Engineering from Tribhuvan University, Nepal. She conducted her PhD research within the NWO-funded project CAtchment Strategies TOwards Resilience (CASTOR) at the Faculty of Technology, Policy and Management of the Delft University of Technology.

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