A living lab learning framework rooted in learning theories

Bhatta, Astha; Vreugdenhil, Heleen; Slinger, Jill

DOI
10.1016/j.eiar.2025.107894

Publication date
2025

Document Version
Final published version

Published in
Environmental Impact Assessment Review

Citation (APA)
Bhatta, A., Vreugdenhil, H., & Slinger, J. (2025). A living lab learning framework rooted in learning theories. *Environmental Impact Assessment Review*, *114*, Article 107894. https://doi.org/10.1016/j.eiar.2025.107894

Environmental Impact Assessment Review 114 (2025) 107894

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

journal homepage: www.elsevier.com/locate/eiar

A living lab learning framework rooted in learning theories

Astha Bhatta [a,b,*], Heleen Vreugdenhil [a,b], Jill Slinger [a,c]

[a] Delft University of Technology, Faculty of Technology, Policy and Management, Department of Multi-Actor Systems, Jaffalaan 5, 2628 BX, Delft, the Netherlands
[b] Deltares, PO Box 177, 2600 MH Delft, the Netherlands
[c] Institute for Water Research, Rhodes University, PO Box 94, Makhanda 6140, South Africa

ARTICLE INFO

Keywords:
Learning framework
Learning theories
Co-creation activities
Innovation impacts
Impact assessment

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 co-creative 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.

1. Introduction

Complex societal challenges, such as establishing sustainable land and water management, demand an integrated approach and engagement of relevant stakeholders (Bhatta et al., 2023a; Eberle et al., 2021). Spanning across technical, organizational, social, and political dimensions, these challenges are inherently dynamic and multifaceted (Bhatta et al., 2023b; 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., 2023b). 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 and 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 and Westerlund, 2015), 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 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 and Pawar, 2012; Westerlund and Leminen, 2011), (3) a transdisciplinary and multi-stakeholder 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

* Corresponding author at: Delft University of Technology, Department of Multi-Actor Systems, Faculty of Technology, Policy and Management, Jaffalaan 5, 2628 BX, Delft, the Netherlands.
E-mail address: a.bhatta-1@tudelft.nl (A. Bhatta).

https://doi.org/10.1016/j.eiar.2025.107894
Received 8 August 2024; Received in revised form 25 February 2025; Accepted 28 February 2025
Available online 12 March 2025

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., 2023b; Hilbers et al., 2024). Recent research positions living lab 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. (2023) 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., 2023b; 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 and 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, 2004; Howells, 2002). Thus, knowledge exchange, mutual learning, and interactions during co-creation lead to innovative outcomes and impacts (De Silva et al., 2023; Sánchez and Mitchell, 2017). The success of co-creation 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 and 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 and 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 and 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 and 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.

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, 2020; 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 (Fig. 1) (Cronjé, 2006; Jonassen, 1991).

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 (Ataro, 2020). 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 and 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-

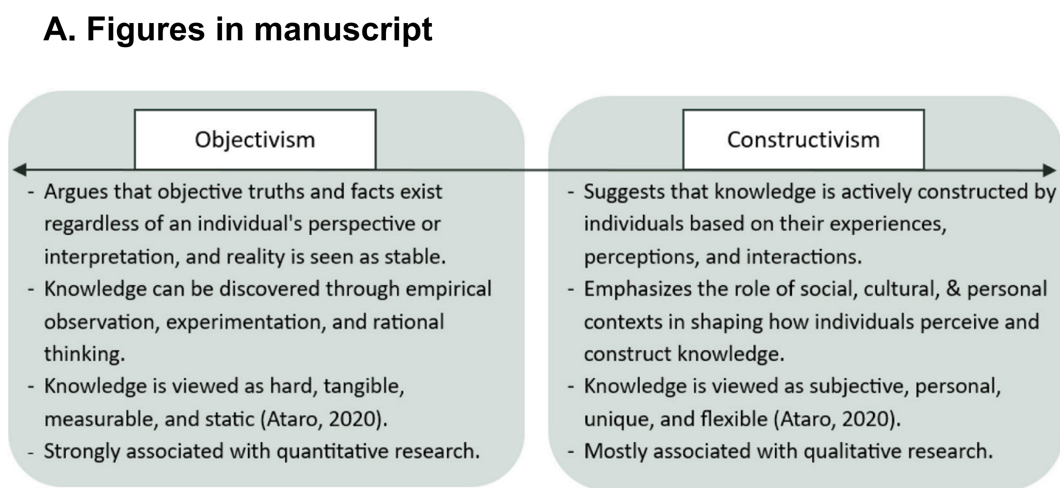


Fig. 1. Objectivism and constructivism continuum.

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 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. 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 and 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. (2023b), define the core characteristics as: based in "real-life setting", pursuing "innovation", "user-centered" ("co-creative"), and involvement of "multi-stakeholders" ("quadruple-helix"), 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 (Fig. 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 *1)*. A complete list, including titles and the learning theories utilized in these papers, is available in the supplementary material **A** (table A-C; chart A).

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 Fig. 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.

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 supplementary material **A**, 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,

Table 1
Keywords used for search in Scopus + WOS.

					No. of papers
"Learning theor*"	AND	"Real-life setting"	*OR*	"Real-life context"	13
		"innovation"	*AND*	Doc type "review"	66
		"User-centered"	*OR*	"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

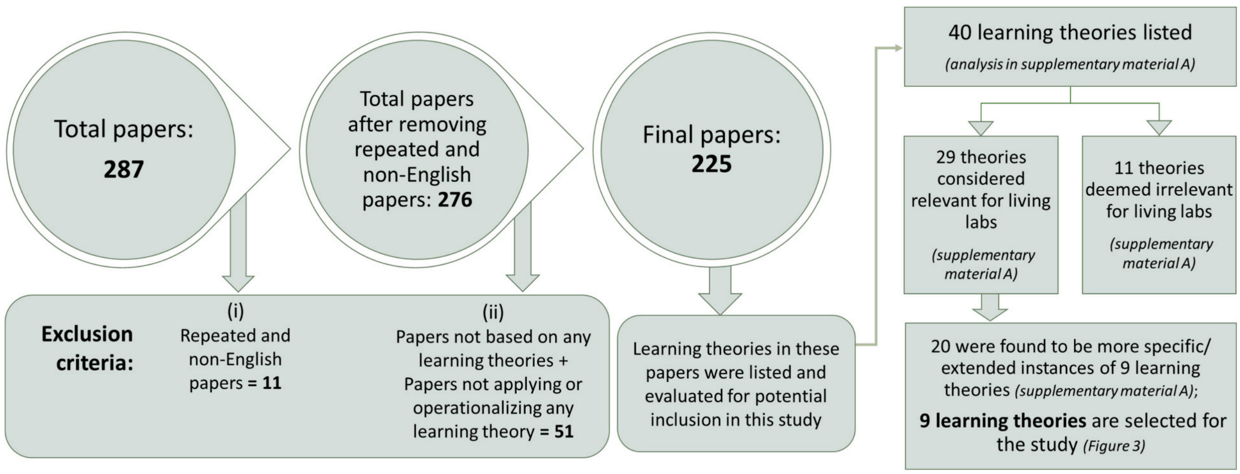


Fig. 2. Strategy adopted to select the papers and learning theories applicable to this study.

40 learning theories were listed (supplementary material A, 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 supplementary material **A**; Table E). The nine theories are presented in result section (Fig. 3). 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 and 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 and Thölke, 2010). Learning types were distinguished as instrumental (substantive) knowledge, practical capacity learning, communicative knowledge,

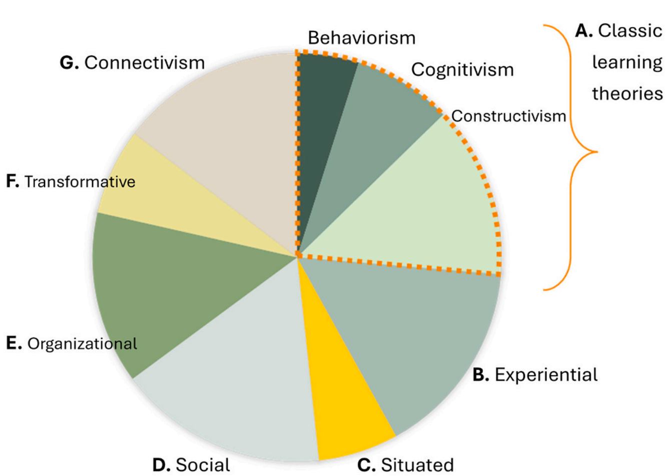


Fig. 3. Learning theories relevant to the characteristics of living labs.

network knowledge, and critical reflection based on the work of Cranton (2001), Vreugdenhil et al. (2010), and Galway et al. (2016). Similarly, for each learning theory, the central learning process was identified. Finally, we built our understanding of learning levels based on Ropes and Thölke (2010), Huber (1991), and Sessa and London (2015) as individual, group, and organizational levels. All these inputs were used to realize the *Living Lab Learning Framework*.

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 Fig. 3.

The learning theories numbered (A-G) are summarized in Table 2 of section 4.1 and explained in detailed in the supplementary material **B** (along with the insights on the need to connect these theories and the possible links between modern learning theories). Section 4.2 provides illustrative examples of how these theories have been used or can be operationalized in a living lab context, and Table 3 shows the relationship between the identified learning theories and living lab characteristics. Section 4.3 develops a living lab learning framework, based on Table 4, where Table 4 connects key concepts (italicized) in each learning theory with the components (bolded) of the learning framework. Section 4.4 then highlights the added value of the living lab learning framework.

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 supplementary material **B**, and summarized in Table 2, column 1. Table 2 further organizes these learning theories according to the three key questions posed in *Section 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 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 is acquired through active participation in meaningful activities within a community of practice	knowledge, skills, and tactics are co-constructed 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 & Cole, 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 and 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 (Hendricks, 2019; Masethe et al., 2017)	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

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

As mentioned at the start of section 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.

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 and 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 real-world contexts, adaptive learning, and active participation, can be observed in living labs (Van der Horst and 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 Knickel et al. (2023) and Blezer et al. (2024), 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

Table 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 multi-stakeholder	Digitalization	Sustainability
Experiential LT (Masethe et al., 2017; 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, thus driving innovation guided by feedback loops, e.g., product development**	**Users participate actively in designing experiments and reflecting on their outcomes. E.g., users try out a new soil health app and suggest refining points**	Thrives on diverse perspectives during observation and experimentation phases, especially during living lab activities	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, real-world 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 toward 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 (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 learning in LLs**	Digital platforms enhance interaction, engagement, & support shared learning experiences	Shared learning may foster sustainable behaviors
Organizational LT (Argote, 2012; Dutta and 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 thinking 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 (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 LLs 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					

digital spaces, online communities, and virtual or augmented realities (Bhatta et al., 2023b), connecting individuals to diverse information and expertise.

Some living labs are guided by design-based learning (Brankaert and den Ouden, 2017; Trei et al., 2021), action-research, citizen science (Oliveira, 2022; Willis and Gupta, 2023), problem- or project-based learning, and game-based learning, (Borgford-Parnell et al., 2010; Moffett and Cassidy, 2023; Taajamaa et al., 2013). These approaches appear to be a natural fit for living labs with their emphasis on user-centeredness, 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 and 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).

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 4.1, using the three major questions from *Section 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 2, which categorized the learning theories into three interacting components: learning types, processes, and levels. These components were further themed into sub-components and presented in Table 4. These components together led to the development of an analytical living lab learning framework, shown in Fig. 4. This framework allows identifying the nature of the knowledge acquired, the processes through which learning occurs, and the entities

Table 4
Explicating connections between *the concepts (in italics*) of the learning theories and the living lab learning framework **components (in bold)**.

	Theories	Learning Type (nature of knowledge)	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)*
	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., 2017)*	**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; Lave and Wenger, 1991)*	**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 and Von Hippel, 1997)*
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 and Cole, 1978)*	*Learning occurs as a* **byproduct** *of observing others during interactions (Vygotsky and Cole, 1978)*	**Individual + Team + broader:** *Individuals learn within teams and broader societal systems; Early work is conceptualized as individual learning influenced by imitating others (Bandura, 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 and 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 (Hendricks, 2019; Masethe et al., 2017)*	*Learning happens* **organically** *through navigating, connecting, and engaging with a network of information sources (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*

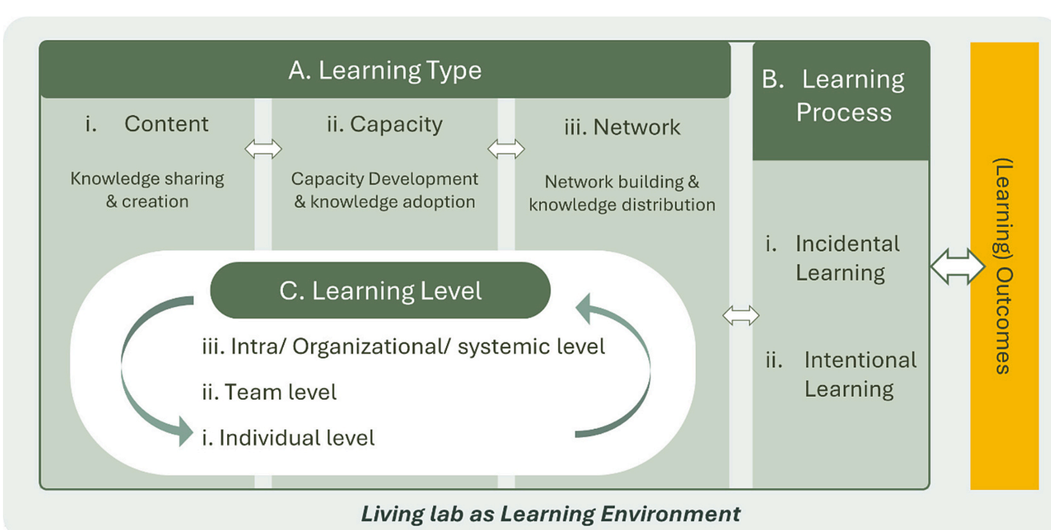


Fig. 4. Analytical learning framework for living labs as a learning environment.

involved in learning within living labs, thereby allowing to capture living lab outcomes beyond their immediate results.

4.3.1. 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 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 in applying the sharing or created information, methods, or concepts in an existing and new situation and being able to make decisions in selecting certain approaches based on the 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 and 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 and 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.

4.3.2. 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. Here, a pragmatic stance on learning processes as *intentional* (i.e., formalized) or *incidental* (i.e., adhoc) is adopted (Table 4) (Kørnøv et al., 2022; Light, 2006).

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 et al., 2023b). 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 and Watkins, 2001). This process involves unintentional or unplanned learning that occurs as a byproduct of organized activities or experiences (Marsick and 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 and Smit, 2024; Sauer and Copeland, 2021).

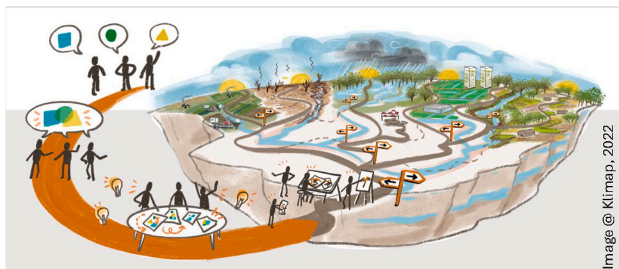
4.3.3. Learning levels

'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 and 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 and 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 4). Cognitive and experimental learning occurs 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 and 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

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. (2025)



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).

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.

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 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. (2023b). 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.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests.

This work is undertaken within the project CAtchment Strategies TOwards Resilience (CASTOR): Dutch Pleistocene landscapes in the Anthropocene [project number NWA.1292.19.362], financed by the Dutch Research Council (NWO). JHS and HV are also supported by the Multi-Actor Systems Research Programme of the Delft University of Technology. HV is further supported by Stichting Deltares.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eiar.2025.107894.

Data availability

No data was used for the research described in the article.

References

Alamanos, A., Koundouri, P., Papadaki, L., Pliakou, T., Toli, E., 2022. Water for tomorrow: a living lab on the creation of the science-policy-stakeholder Interface [article]. Water (Switzerland) 14 (18). https://doi.org/10.3390/w14182879. Article 2879.

Andrade, R., van Riper, C.J., Goodson, D., Johnson, D.N., Stewart, W., 2022. Learning pathways for engagement: understanding drivers of pro-environmental behavior in the context of protected area management. J. Environ. Manag. 323, 116204.

Argote, L., 2012. Organizational Learning: Creating, Retaining and Transferring Knowledge. Springer Science & Business Media.

Arksey, H., O'Malley, L., 2005. Scoping studies: towards a methodological framework. Int. J. Soc. Res. Methodol. 8 (1), 19–32.

Ataro, G., 2020. Methods, methodological challenges and lesson learned from phenomenological study about OSCE experience: overview of paradigm-driven qualitative approach in medical education. Ann. Med. Surg. 49, 19–23.

Backhaus, J., Böschen, S., John, S., Altepost, A., Cloppenburg, F., Fahy, F., Gäckle, J., Gries, T., Heckwolf, C., Matschoss, K., 2023. Living lab. In: Handbook Transdisciplinary Learning. Transcript verlag, pp. 235–244.

Barfi, K.A., Bervell, B., Arkorful, V., 2021. Integration of social media for smart pedagogy: initial perceptions of senior high school students in Ghana. Educ. Inf. Technol. 26 (3), 3033–3055. https://doi.org/10.1007/s10639-020-10405-y.

Barraclough, A.D., Reed, M.G., Coetzer, K., Price, M.F., Schultz, L., Moreira-Muñoz, A., Måren, I., 2023. Global knowledge–action networks at the frontlines of sustainability: insights from five decades of science for action in UNESCO's world network of biosphere reserves. People Nat. 5 (5), 1430–1444.

Bell, P., 2004. On the theoretical breadth of design-based research in education. Educ. Psychol. 39 (4), 243–253.

Bhatta, A., Le, T.M., Wetser, K., Kujawa-Roeleveld, K., Rijnaarts, H.H., 2023a. Stakeholder-based decision support model for selection of alternative water sources-a path towards sustainable industrial future in Vietnam. J. Clean. Prod. 385, 135539.

Bhatta, A., Vreugdenhil, H., Slinger, J., 2023b. Characterizing nature-based living labs from their seeds in the past. Environment. Develop. 100959.

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

Biberhofer, P., Rammel, C., 2017. Transdisciplinary learning and teaching as answers to urban sustainability challenges. Int. J. Sustain. High. Educ. 18 (1), 63–83.

Blezer, S., Abujidi, N., Sap, H., 2024. Urban living labs as innovation infrastructure for local urban intervention acceleration and student social learning: the impacts on community wellbeing in Heerlen. Front. Public Health 11, 1242151.

Borgford-Parnell, J., Deibel, K., Atman, C.J., 2010. From engineering design research to engineering pedagogy: bringing research results directly to the students. Int. J. Eng. Educ. 26 (4), 748.

Boström, M., Andersson, E., Berg, M., Gustafsson, K., Gustavsson, E., Hysing, E., Lidskog, R., Löfmarck, E., Ojala, M., Olsson, J., 2018. Conditions for transformative learning for sustainable development: a theoretical review and approach. Sustainability 10 (12), 4479.

Brankaert, R., den Ouden, E., 2017. The design-driven living lab: a new approach to exploring solutions to complex societal challenges. Technol. Innov. Manag. Rev. 7 (1).

Carman, J.M., 2002. Blended Learning Design: Five Key Ingredients. https://facilitatedadultlearning.pbworks.com/f/Blended_20Learning_20Design_1028.pdf.

Chroneer, D., Stahlbrost, A., Habibipour, A., 2019. Urban living labs: towards an integrated understanding of their key components [article]. Technol. Innov. Manag. Rev. 9 (3), 50–62. https://doi.org/10.22215/TIMREVIEW/1224.

Cinar, E., Demircioglu, M.A., Acik, A.C., Simms, C., 2024. Public sector innovation in a city state: exploring innovation types and national context in Singapore. Res. Policy 53 (2), 104915.

Compagnucci, L., Spigarelli, F., Coelho, J., Duarte, C., 2021. Living labs and user engagement for innovation and sustainability. J. Clean. Prod. 289, 125721.

Conradie, P., 2014. Supporting self-directed learning by connectivism and personal learning environments. Int. J. Inf. Educ. Technol. 4 (3), 254–259.

Corazza, L., Cisi, M., Scagnelli, S.D., 2018. Creation of shared value in action: the case of a living lab using transformative learning. J. Busin. Ethics Educat. 15, 235–258.

Cranton, P., 2001. Interpretive and critical evaluation. New Dir. Teach. Learn. 2001 (88).

Cronjé, J., 2006. Paradigms regained: toward integrating objectivism and constructivism in instructional design and the learning sciences. Educ. Technol. Res. Dev. 54, 387–416.

Cronjé, J., 2020. Towards a new definition of blended learning. Electron. J. e-Learn. 18 (2), 114–121. https://doi.org/10.34190/EJEL.20.18.2.001.

Crossan, M.M., Lane, H.W., White, R.E., 1999. An organizational learning framework: from intuition to institution. Acad. Manag. Rev. 24 (3), 522–537.

Cruz, J., Bruhis, N., Kellam, N., Jayasuriya, S., 2021. Students' implicit epistemologies when working at the intersection of engineering and the arts. Int. J. STEM Educ. 8 (1), 29. https://doi.org/10.1186/s40594-021-00289-w.

Curnow, J., 2022. Resituating situated learning within racialized and colonial social relations. Mind Cult. Act. 29 (4), 301–315.

Dangwal, K.L., 2017. Blended learning: an innovative approach. Univ. J. Educ. Res. 5 (1), 129–136.

Daniels, S.E., Walker, G.B., 1996. Collaborative learning: improving public deliberation in ecosystem-based management. Environ. Impact Assess. Rev. 16 (2), 71–102.

de Kraker, J., 2017. Social learning for resilience in social–ecological systems. Curr. Opin. Environ. Sustain. 28, 100–107. https://doi.org/10.1016/j.cosust.2017.09.002.

De Silva, M., Al-Tabbaa, O., Pinto, J., 2023. Academics engaging in knowledge transfer and co-creation: push causation and pull effectuation? Res. Policy 52 (2), 104668.

Du Preez, M., Arkesteijn, M.H., den Heijer, A.C., Rymarzak, M., 2022. Campus Managers' role in innovation implementation for sustainability on Dutch university campuses. Sustainability 14 (23), 16251.

Dutta, D.K., Crossan, M.M., 2005. The nature of entrepreneurial opportunities: understanding the process using the 4I organizational learning framework. Entrep. Theory Pract. 29 (4), 425–449.

Ebbesson, E., Lund, J., Smith, R.C., 2024. Dynamics of sustained co-design in urban living labs. CoDesign 1–18.

Eberle, J., Stegmann, K., Barrat, A., Fischer, F., Lund, K., 2021. Initiating scientific collaborations across career levels and disciplines–a network analysis on behavioral data. Int. J. Comput.-Support. Collab. Learn. 16 (2), 151–184.

Eddy, P.L., Hao, Y., Markiewicz, C., Iverson, E., 2019. Faculty change agents as adult learners: the power of situated learning. Community Coll. J. Res. Pract. 43 (8), 539–555.

Edwards-Schachter, M.E., Matti, C.E., Alcántara, E., 2012. Fostering quality of life through social innovation: a living lab methodology study case [article]. Rev. Policy Res. 29 (6), 672–692. https://doi.org/10.1111/j.1541-1338.2012.00588.x.

Eriksson, M., Niitamo, V.-P., Kulkki, S., 2005. State-of-the-art in utilizing Living Labs approach to user-centric ICT Innovation-a European approach. In: Lulea: Center for Distance-Spanning Technology. Lulea University of Technology Sweden, Lulea.

Fagerberg, J., 2004. Innovation: A Guide to the Literature.

Frick-Trzebitzky, F., Kluge, T., Stegemann, S., Zimmermann, M., 2022. Capacity development for water reuse in in-formal partnerships in northern Namibia. Front. Water 4, 906407.

Galway, L.P., Parkes, M.W., Allen, D., Takaro, T.K., 2016. Building interdisciplinary research capacity: a key challenge for ecological approaches in public health. AIMS Public Health 3 (2), 389. https://doi.org/10.3934/publichealth.2016.2.389.

Gamache, G., Anglade, J., Feche, R., Barataud, F., Mignolet, C., Coquil, X., 2020. Can living labs offer a pathway to support local agri-food sustainability transitions? *Environmental Innovation and Societal*. Transitions 37, 93–107.

Gibson, S.K., 2004. Social learning (cognitive) theory and implications for human resource development. Adv. Dev. Hum. Resour. 6 (2), 193–210.

Glassner, A., Back, S., Glassner, A., Back, S., 2020. Three "gogies": pedagogy, andragogy, heutagogy. In: Exploring Heutagogy in Higher Education: Academia Meets the Zeitgeist, pp. 59–74.

Hafit, N.I.A., Anis, A., Johan, Z.J., Othman, N.A., Munir, Z., 2022. Examining the role of Organisational learning theory and learning Organisations in the era of digitalization: a literature review. Int. J. Acad. Res. Bus Soci. Sci. 12 (5), 740–752.

Hagy, S., Morrison, G.M., Elfstrand, P., 2017. Co-creation in living labs. In: Keyson, D.V., Guerra-Santin, O., Lockton, D. (Eds.), Living Labs: Design and Assessment of Sustainable Living. Springer International Publishing, pp. 169–178. https://doi.org/10.1007/978-3-319-33527-8_13.

Harasim, L., 2017. Learning theories: the role of epistemology, science, and technology. In: Learning, Design, and Technology, Np. Springer, Cham.

Heath, G., 2014. The scholarship of knowledge in the modernised university. In: Advancing Knowledge in Higher Education: Universities in Turbulent Times. IGI Global, pp. 218–234.

Hendricks, V.F., 2006. Mainstream and Formal Epistemology. Cambridge University Press.

Hendricks, G.P., 2019. Connectivism as a learning theory and its relation to open distance education. Progressio 41 (1), 1–13.

Hermans, L.M., Cunningham, S., Slinger, J.H., 2013. Adaptive co-management and learning: developments in coastal management in the Netherlands from 1985 to 2010. Water Co-Manag. 266–291.

Hilbers, A.M., Sijtsma, F.J., Busscher, T., Arts, J., 2024. Size matters! Using conjoint analysis to uncover public preferences for design optimisation in road infrastructure EIAs. Environ. Impact Assess. Rev. 104, 107349. https://doi.org/10.1016/j.eiar.2023.107349.

Holmes, K., Preston, G., 2020. Concept of pedagogy and andragogy education. Communi. Med. Educat. J. 1 (1), 12–18.

Hosseini, Z., Okkonen, J., 2022. Web-based learning for cultural adaptation: constructing a digital portal for Persian speaking immigrants in Finland. Intelligent Computing 1.

Howells, J.R., 2002. Tacit knowledge, innovation and economic geography. Urban Stud. 39 (5–6), 871–884.

Huang, J.H., Thomas, E., 2021. A review of living lab research and methods for user involvement. Technol. Innov. Manag. Rev. 11, 88–107. https://doi.org/10.22215/timreview/1467.

Huber, G.P., 1991. Organizational learning: the contributing processes and the literatures. Organ. Sci. 2 (1), 88–115.

Illeris, K., 2003. Workplace learning and learning theory. J. Work. Learn. 15 (4), 167–178.

Jaśkiewicz, T., Smit, I., 2024. Between experiments leveraging prototypes to trigger, articulate, and share informal knowledge: Case of the cities of things living lab. In: Applied Design Research in Living Labs and Other Experimental Learning and Innovation Environments. CRC Press, pp. 210–233.

Jonassen, D.H., 1991. Objectivism versus constructivism: do we need a new philosophical paradigm? Educ. Technol. Res. Dev. 39, 5–14.

Jung, I., 2019. Connectivism and Networked Learning. In: Jung, I. (Ed.), *Open and Distance Education Theory Revisited: Implications for the Digital Era*. Springer, Singapore, pp. 47–55. https://doi.org/10.1007/978-981-13-7740-2_6.

Kelly, G.J., McDonald, S., Wickman, P.-O., 2012. Science learning and epistemology. In: Second International Handbook of Science Education, pp. 281–291.

Knickel, M., Caniglia, G., Knickel, K., Šūmane, S., Maye, D., Arcuri, S., Keech, D., Tisenkopfs, T., Brunori, G., 2023. Lost in a haze or playing to partners' strengths? Learning to collaborate in three transdisciplinary European living labs. Futures 152, 103219. https://doi.org/10.1016/j.futures.2023.103219.

Koens, K., Stompff, G., Vervloed, J., Gerritsma, R., Horgan, D., 2024. How deep is your lab? Understanding the possibilities and limitations of living labs in tourism. J. Destin. Mark. Manag. 32, 100893.

Kohlgrüber, M., Maldonado-Mariscal, K., Schröder, A., 2021. Mutual Learning in Innovation and Co-Creation Processes: Integrating Technological and Social Innovation. Frontiers in Education 6. https://doi.org/10.3389/feduc.2021.49866.

Kolb, D.A., Boyatzis, R.E., Mainemelis, C., 2014. Experiential learning theory: Previous research and new directions. In: *Perspectives on thinking, learning, and cognitive styles*. Routledge, pp. 227–247.

Kørnøv, L., Larsen, S.V., Lyhne, I., Puibaraud, I.E., Hansen, A.M., Aaen, S.B., Nielsen, H. N., 2022. Collaboration through environmental assessment networks: co-creating space and cultivating a joint learning mindset. Environ. Impact Assess. Rev. 97, 106898. https://doi.org/10.1016/j.eiar.2022.106898.

Lave, J., Wenger, E., 1991. *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Lehmann, V., Frangioni, M., Dubé, P., 2015. Living lab as knowledge system: an actual approach for managing urban service projects? [article]. J. Knowl. Manag. 19 (5), 1087–1107. https://doi.org/10.1108/JKM-02-2015-0058.

Leminen, S., Westerlund, M., 2012. Towards innovation in living labs networks [article]. Int. J. Prod. Dev. 17 (1–2), 43–49. https://doi.org/10.1504/IJPD.2012.051161.

Leminen, S., Westerlund, M., 2015. Incremental and radical service innovation in living labs. In: Economics: Concepts, Methodologies, Tools, and Applications. IGI Global, pp. 445–459. https://doi.org/10.4018/978-1-4666-8468-3.ch025.

Light, R., 2006. Situated learning in an Australian surf club. Sport Educ. Soc. 11 (2), 155–172.

Lupp, G., Zingraff-Hamed, A., Huang, J.J., Oen, A., Pauleit, S., 2021. Living labs—a concept for co-designing nature-based solutions [article]. Sustainability (Switzerland) 13 (1), 1–22. Article 188. https://doi.org/10.3390/su13010188.

Lux, A., Schäfer, M., Bergmann, M., Jahn, T., Marg, O., Nagy, E., Ransiek, A.-C., Theiler, L., 2019. Societal effects of transdisciplinary sustainability research—how can they be strengthened during the research process? Environ. Sci. Pol. 101, 183–191.

Marselis, S.M., Hannula, S.E., Trimbos, K.B., Berg, M.P., Bodelier, P.L., Declerck, S.A., Erisman, J.W., Kuramae, E.E., Nanu, A., Veen, G.C., 2024. The use of living labs to advance agro-ecological theory in the transition towards sustainable land use: a tale of two polders. Environ. Impact Assess. Rev. 108, 107588.

Marsick, V.J., Watkins, K.E., 2001. Informal and incidental learning. New Direct. Adult Continuing Educat.3 2001 (89), 25–34.

Masethe, M.A., Masethe, H.D., Odunaike, S.A., 2017. Scoping review of learning theories in the 21st century. In: Proceedings of the World Congress on Engineering and Computer Science.

Matsekoleng, T.K., 2021. Action research and environmental education within a home-based setup to conscientise children towards littering. Environ. Dev. Sustain. 23 (10), 14163–14175.

Mezirow, J., 2018. Transformative learning theory. In: Contemporary Theories of Learning. Routledge, pp. 114–128.

Mitiku, H., Herweg, K.G., Stillhardt, B., 2006. Sustainable Land Management: A New Approach to Soil and Water Conservation in Ethiopia.

Moffett, J., Cassidy, D., 2023. Building a digital educational escape room using an online design-thinking process. Online Learn. 27 (2), 223–244.

Muhajirah, M., 2020. Basic of learning theory:(behaviorism, cognitivism, constructivism, and humanism). Int. J. Asian Stud. 1 (1), 37–42.

O'Brien, W., Doré, N., Campbell-Templeman, K., Lowcay, D., Derakhti, M., 2021. Living labs as an opportunity for experiential learning in building engineering education. Adv. Eng. Inform. 50, 101440.

Oliveira, R., 2022. FoodLink—A network for driving food transition in the Lisbon metropolitan area. Land 11 (11), 2047.

Palgan, Y.V., McCormick, K., Evans, J., 2018. Urban living labs: Catalysing low carbon and sustainable cities in Europe?. In: Urban Living Labs: Experimenting with City Futures. Taylor and Francis, pp. 21–36. https://doi.org/10.4324/9781315230641.

Pallot, M., Pawar, K., 2012. A holistic model of user experience for living lab experiential design. In: 2012 18th International ICE Conference on Engineering, Technology and Innovation.

Puerari, E., De Koning, J.I., Von Wirth, T., Karré, P.M., Mulder, I.J., Loorbach, D.A., 2018. Co-creation dynamics in urban living labs. Sustainability 10 (6), 1893.

Quay, J., 2003. Experience and participation: relating theories of learning. J. Exp. Educ. 26 (2), 105–112.

Rădulescu, M.A., Leendertse, W., Arts, J., 2022. Living labs: A creative and collaborative planning approach. In: Franklin, A. (Ed.), Co-Creativity and Engaged Scholarship: Transformative Methods in Social Sustainability Research. Springer International Publishing, pp. 457–491. https://doi.org/10.1007/978-3-030-84248-2_15.

Rannikmäe, M., Holbrook, J., Soobard, R., 2020. Social constructivism—Jerome Bruner. In: Science Education in Theory and Practice: An Introductory Guide to Learning Theory, pp. 259–275.

Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C., 2010. What is social learning? Ecol. soc. 15 (4).

Rill, B., Hämäläinen, M., 2018. The Art of Co-Creation, vol. 10. Springer, Singapore, pp. 978–981.

Romijn, B.R., Slot, P.L., Leseman, P.P., 2021. Increasing teachers' intercultural competences in teacher preparation programs and through professional development: a review. Teach. Teach. Educ. 98, 103236.

Ropes, D., Thölke, J., 2010. Communities of practice: finally a link between individual and organizational learning in management development programs. In: Proceedings of the European Conference on Intellectual Capital.

Ruiz-Ocampo, H., Katusic, V., Demetriou, G., 2023. Closing the loop in water management. In: Water Management and Circular Economy, pp. 3–24. https://doi.org/10.1016/B978-0-323-95280-4.00008-4.

Rukspollmuang, C., Chansema, T., 2024. Promoting sustainability literacy for students in Thai higher education institution: a case of Siam university. Int. J. Comparat. Educat. Develop. 26 (3), 286–306.

Russell, S.S., 2006. An overview of adult-learning processes. Urol. Nurs. 26 (5).

Sabri, S.B., 2017. An objectivist-constructivist blended approach for teaching university-level beginner string technique class: a conceptual framework. Int. J. Educ. Res. 5.

Sánchez, L.E., Mitchell, R., 2017. Conceptualizing impact assessment as a learning process. Environ. Impact Assess. Rev. 62, 195–204. https://doi.org/10.1016/j.eiar.2016.06.001.

Sauer, S., Copeland, S., 2021. Wa/ondering with data-or, responsibly measuring socio-technical serendipity in the urban environment. In: 2021 IEEE International Smart Cities Conference (ISC2).

Schuurman, D., 2015. Bridging the Gap between Open and User Innovation?: Exploring the Value of Living Labs as a Means to Structure User Contribution and Manage Distributed Innovation Ghent University.
Sessa, V.I., London, M., 2015. Continuous Learning in Organizations: Individual, Group, and Organizational Perspectives. Psychology Press.
Sinclair, A.J., Diduck, A., Fitzpatrick, P., 2008. Conceptualizing learning for sustainability through environmental assessment: critical reflections on 15 years of research. Environ. Impact Assess. Rev. 28 (7), 415–428.
Singer-Brodowski, M., 2023. The potential of transformative learning for sustainability transitions: moving beyond formal learning environments. Environ. Dev. Sustain. 1–19.
Soetanto, D.P., van Geenhuizen, M., 2011. Social networks, university spin-off growth and promises of 'living labs'. Reg. Sci. Policy Pract. 3 (3), 305–322.
Ståhlbröst, A., 2008. Forming Future IT: The Living Lab Way of User Involvement Luleå Tekniska Universitet.
Steffens, K., 2015. Competences, learning theories and MOOC s: Recent developments in lifelong learning. Eur. J. Educ. 50 (1), 41–59.
Stockstrom, C.S., Goduscheit, R.C., Lüthje, C., Jørgensen, J.H., 2016. Identifying valuable users as informants for innovation processes: comparing the search efficiency of pyramiding and screening. Res. Policy 45 (2), 507–516.
Stoten, D.W., 2024. Positioning through epistemic cognition in higher education: conceptualising the ways in which academics in a business school view heutagogy. High. Educ. 87 (4), 991–1007.
Taajamaa, V., Kirjavainen, S., Repokari, L., Sjöman, H., Utriainen, T., Salakoski, T., 2013. Dancing with ambiguity design thinking in interdisciplinary engineering education. In: 2013 IEEE Tsinghua International Design Management Symposium.
Tasir, Z., Hao, W., 2024. Development of a theoretical framework of MOOCs with gamification elements to enhance Students' higher-order thinking skills: a critical review of the literature. J. Informat. Technol. Educat.: Res. 23 (1).
Travers, N.L., Jankowski, N., Bushway, D.J., Duncan, A.G., 2019. Learning Frameworks: Tools for Building a Better Educational Experience. In: Lumina Issue Paper. Lumina Foundation.
Trei, D.T., Hornung, J., Rychlik, J., Bandelow, N.C., 2021. From political motivation to scientific knowledge: classifying policy labs in the science-policy nexus. Eur. Plan. Stud. 29 (12), 2340–2356.
Tusting, K., Barton, D., 2003. Models of Adult Learning: A Literature Review. NIACE UK.
Tyre, M.J., Von Hippel, E., 1997. The situated nature of adaptive learning in organizations. Organ. Sci. 8 (1), 71–83.
Unger, A., de Bronstein, A.A., Timoschenko, T., 2022. Transdisciplinary learning experiences in an urban living lab: practical seminars as collaboration format. Transform. Entrepren. Educat. 135–151.
van den Berg, L.M., Dingkuhn, E.L., Meehan, N., O'Sullivan, L., 2023. Investigating bottlenecks hampering the adoption of water quality-enhancing practices for sustainable land management in Ireland. J. Environ. Manag. 345, 118741.
Van der Horst, D., Staddon, S., 2018. Types of learning identified in reflective energy diaries of post-graduate students. Energ. Effic. 11 (7), 1783–1795.
Von Zedtwitz, M., 2002. Organizational learning through post–project reviews in R&D. R&D Manag. 32 (3), 255–268.
Vreugdenhil, H., Slinger, J., Thissen, W., Rault, P.K., 2010. Pilot projects in water management. Ecol. Soc. 15 (3).
Vygotsky, L.S., Cole, M., 1978. *Mind in society: Development of higher psychological processes*. Harvard university press.
Westerlund, M., Leminen, S., 2011. Managing the challenges of becoming an open innovation company: experiences from living labs. Technol. Innov. Manag. Rev. 1 (1).
Willis, K., Gupta, A., 2023. Place-keeping in the park: testing a living lab approach to facilitate nature connectedness in urban greenspaces. Sustainability 15 (13), 9930.
Zada, M., Khan, J., Saeed, I., Zada, S., Jun, Z.Y., 2023. Linking public leadership with project management effectiveness: Mediating role of goal clarity and moderating role of top management support. Heliyon 9 (5).
Zunariyah, S., Demartoto, A., Ramdhon, A., 2018. A transformative education model for disaster-resilient child. Humanit. & Soc. Sci. Rev. 6 (3), 55–60.