Characteristics and challenges of teaching and learning in sustainability-oriented Living Labs within higher education: a literature review

Marlies L.E. van der Wee
School of Built Environment, Rotterdam University of Applied Sciences, Rotterdam, The Netherlands and Education and Learning Sciences Group, Wageningen University and Research, Wageningen, The Netherlands

Valentina C. Tassone and Arjen E.J. Wals
Education and Learning Sciences Group, Wageningen University and Research, Wageningen, The Netherlands, and

Peter Troxler
Research Centre Creating 010, Rotterdam University of Applied Sciences, Rotterdam, The Netherlands

Received 5 October 2023
Revised 21 December 2023
8 April 2024
Accepted 24 April 2024

Abstract

Purpose – This study aims to bring together the available scattered knowledge about teaching and learning in Living Labs within higher education, and to explore their potential for supporting students' sustainability-oriented transformative learning.

Design/methodology/approach – A literature review was conducted, applying a realist approach. A sample of 35 articles was analyzed qualitatively, mapping the data according to the realist constructs "context," "intervention," "mechanism" and "outcome" and using the constant comparison method for data analysis.

Findings – This study identified multiple characteristics of teaching and learning in sustainability-oriented Living Labs, namely, two socio-physical teaching and learning contexts, two pedagogical approaches as

The authors are grateful for the inspiration offered by colleagues and friends at Rotterdam University of Applied Sciences and the community of regenerative educators and practitioners. Thank you, Ilona Plessius, Ted Veldkamp and Ingeborg Heezen for your comments on draft versions of this article; Mieke Lopes-Cardozo and Ben Haggard for your reflective questions about the regenerative potential of this work; ginger coons for the language and editorial improvements; Lucas van der Wee for all your advice on visualizing the articles findings; and the two anonymous reviewers for their constructive comments and feedback.

interventions therein, four learning processes as (potential) mechanisms and six sustainability-related learning outcomes. Two main challenges were also identified.

Originality/value – To the best of the authors' knowledge, this is the first study that brings together the scattered results from previous studies into a comprehensive description of characteristics and challenges of teaching and learning in Living Labs as sustainability-oriented learning spaces in higher education. The findings can support educators in making scientifically grounded informed choices for teaching and learning in Living Labs and inform future empirical studies to examine when, how and why certain characteristics of teaching and learning in Living Labs, as identified in this study, can support sustainability-oriented transformative learning in higher education.

Keywords Sustainability, Learning processes, Higher education, Living labs, Pedagogies

Paper type Literature review

Introduction

Worldwide, people experience the consequences of complex sustainability challenges such as climate change, extreme wealth inequality, environmental degradation and biodiversity loss (IPCC, 2022). As these challenges put the functioning of ecosystems and human well-being at risk, there is an urgent need for responses that balance human activities with those of non-human species and the carrying capacity of supporting ecosystems (Rockström *et al.*, 2021). To develop such responses, scientists and practitioners increasingly point at the need for greater connectivity between science and society (Schneider *et al.*, 2019). They call upon stakeholders from various disciplines and sectors to bridge differences by co-creating scientifically sound and societally relevant responses (Pohl *et al.*, 2017), and by connecting knowledge development, practical experience and learning (Caniglia *et al.*, 2021). Higher education is considered vital in these processes because of its responsibility to foster human development and its potential to empower students in finding pathways toward a sustainable future (Purcell *et al.*, 2019). However, to live up to this responsibility and potential, higher education needs to leave behind its focus on educating students to become competitive workers in service of economic growth. Rather, it needs to support processes of transformation to enable students to engage as whole persons "for" and "with" society and take responsibility for the well-being of the planet and people (Sterling, 2021).

In parallel with the discussion initiated by scientists and practitioners, European educational policies developed in response to the European Green Deal also stress the importance of greater connectivity between science and society and point to the responsibility of higher education in this regard (European Commission, 2022b). Particularly in the context of the New European Bauhaus, the European Commission calls on higher education institutes to redesign their curricula, pedagogies and learning environments in ways that enable students to work on real-life sustainability challenges in collaboration with societal partners and in other settings than the traditional classroom environment (European Commission, 2023). Policies present Living Labs as promising settings for bringing together academic and societal stakeholders and transforming traditional educational environments into collaborative learning spaces (European Commission, 2022a).

As such, Living Labs are an attempt to develop transformative settings for dealing with emerging sustainability challenges at the interface of science and society (Schäpke *et al.*, 2018). An increasing number of higher education institutes participates in Living Labs (Leal Filho *et al.*, 2022) as they offer hands-on opportunities to engage both staff and students in local, context-rich issues while also increasing the institution's societal relevance

(Favaloro *et al.*, 2019; Rivera and Savage, 2020). Previous research describes the potential value of Living Labs for developing the capacity to tackle complex sustainability challenges. For example, Backman *et al.* (2019) and Wals (2019) indicated that learning in Living Labs can support students in understanding the complex nature of sustainability, building agency, tackling challenges collaboratively with stakeholders from different backgrounds and in experimenting with new sustainable practices. However, studies from Lotz-Sisitka *et al.* (2015) and O'Brien *et al.* (2013) suggested that, while the potential is there, Living Labs do not "naturally" assist students in developing the capacity for tackling complex sustainability challenges. Scientists such as Disterheft *et al.* (2013) and Desha *et al.* (2021) even stated that without appropriate practices for teaching and learning, students rather learn to improve existing (unsustainable) practices than to create new, more sustainable ones. In sum, in addition to providing a real-life setting, an authentic context-rich issue, and collaboration with different stakeholders, other aspects of teaching and learning, as well as their normative underpinnings, also influence the quality and the direction of learning.

These critical remarks call for a deeper understanding of the characteristics of teaching and learning in sustainability-oriented Living Labs and for exploring their potential to promote transformation toward sustainability, rather than the reproduction of an (unsustainable) status quo (Balsiger *et al.*, 2017; Lotz-Sisitka *et al.*, 2015). Unfortunately, the available research on teaching and learning in sustainability-oriented Living Labs within higher education is scattered. Studies are mainly singular case (e.g. Dabaieh *et al.*, 2018; Masseck, 2017; Trencher *et al.*, 2015) and address teaching and learning components through examples of activities such as serious-gaming or storytelling, however, not in detail and not connected to sustainability-related learning outcomes (Krütli *et al.*, 2018; van den Heuvel *et al.*, 2021). This study seeks to bring the existing research together in a literature review with the aim to shed light on theories and concepts that underpin teaching and learning activities described in previous studies. With this, the authors wish to contribute to a set of scientifically grounded guiding principles for teaching and learning in sustainability-oriented Living Labs (Katikas and Sotiriou, 2023). The guiding question for this study is:

Q1. What are the characteristics and challenges of teaching and learning in Living Labs as sustainability-oriented learning spaces within higher education?

Following this introduction section, the method section describes how the literature review was conducted. The results section then presents the characteristics and challenges of teaching and learning in sustainability-oriented Living Labs. This is followed by the discussion section that reflects on the results and discusses implications and potential ways forward for both practice and research. Finally, the conclusion briefly summarizes how the findings of this study might inform both future research and practice of sustainability-oriented education in Living Labs.

Method

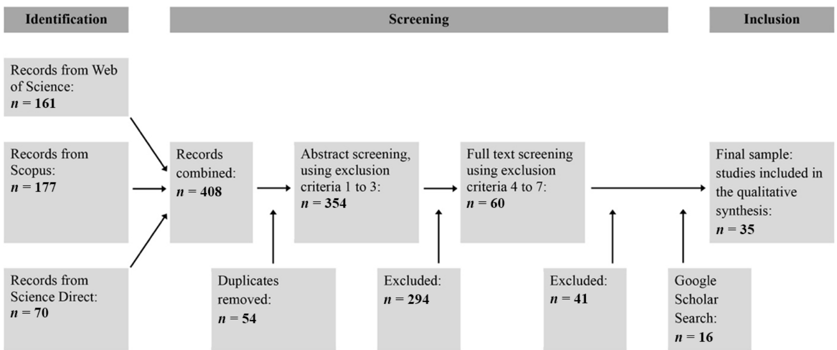
This study draws on a realist review of literature, an approach that recognizes that the outcomes of education are influenced by the interplay of teaching, learning and the features of the environment in which this occur (Versteijlen and Wals, 2023). The aim of a realist review approach is to understand how and why certain interventions (i.e. teaching methods) and mechanisms (i.e. learning processes) generate certain outcomes (i.e. learning outcomes) in a particular context (i.e. the Living Lab as a learning environment) (Wong *et al.*, 2013). Following this line of inquiry, the present study applies the realist approach to understand what is intended or has the potential to generate sustainability-oriented learning outcomes in Living Labs in higher education (Erickson and Gutierrez, 2002). It does so by mapping the characteristics and challenges of teaching and learning in sustainability-oriented Living Labs reported in the literature and subsequently reflecting upon those traits through the lens of relevant (theoretical) articles. Both mapping and reflection are done according to the four analytical constructs of a realist review: "context" as the socio-physical reality e.g. place, relations, institutions, policies; "intervention" as the approach or action that aims to generate a certain outcome; "mechanism" as the response or process that explains why a certain intervention works (or not) in a given context; and "outcome" as the effect of an intervention (Pawson *et al.*, 2005). The authors followed the review steps outlined in Booth *et al.* (2022) which include data collection and selection, data processing and coding and data analysis and synthesis. Each of those steps is further described below.

Data collection

The authors particularly sought peer-reviewed academic articles and conference papers about teaching and learning in sustainability-oriented Living Labs in higher education, which have been published since the establishment of the European Network of Living Labs in 2006 (Leminen and Westerlund, 2019). The process to identify and select articles followed the steps outlined by Booth *et al.* (2022) and is visualized in Figure 1.

To retrieve relevant articles, the authors searched three scientific databases: Web of Science, SCOPUS and Science Direct and applied search strings with the keywords (and synonyms) Living Labs (change labs, innovation labs, field labs), sustainable development (sustainability), higher education (university) and learning (competence development) and applied truncation to include different spellings (such as universit* for university or universities and sustainab* for sustainability or sustainable). Search strings were applied with the settings: article, review, conference paper, in English and published since 2006. The initial search resulted in a sample of 408 publications from the three databases. From the three databases, the authors exported the citation information and the abstract of each retrieved article as a text or CSV file and merged these into a Microsoft Excel spreadsheet. Duplicates were then removed which resulted in a sample of 354 articles.

To determine the relevance for this study, all 354 articles were screened guided by the exclusion criteria presented in Table 1. First, the authors read the abstracts of all articles applying exclusion criteria 1–3. Based on these criteria, 294 articles were excluded because the abstract did not focus on Living Labs as sustainability-oriented environments connected



Source: Authors' own creation/work

Figure 1.
Process of identifying and selecting articles

Screening phase	Aspects	Exclusion criteria
Abstract	Living Labs as environments	1. The abstract refers to Living Labs in a way that is not relevant to our study (e.g. medical labs, digital labs)
	Connection to higher education	2. The abstract describes Living Labs outside the field of higher education (e.g. in urban governance)
	Sustainability orientation	3. The abstract describes Living Labs with other orientations than sustainability
Full text	Living Labs as real-world environments at the interface of education and society	4. The full text addresses Living Labs in a way that is not relevant to our study (e.g. living lab as a simulation)
	Living Labs as learning environments for higher education students	5. The full text does not address the role and activities of students in the Living Lab
		6. The full text does not address practices or approaches for teaching and learning in the Living Lab
	Living Labs as sustainability-oriented learning environments	7. The full text does not refer to a sustainability-related purpose of teaching or learning in Living Labs

Source: Authors' own creation/work

Table 1. Exclusion criteria for abstract and full-text screening

to higher education. The authors then downloaded the 60 remaining articles and read their full text, guided by exclusion criteria 4–7. Based on these criteria, another 41 articles were excluded because they did not focus on teaching and learning in Living Labs as real-world learning environments at the interface of education and society for higher education students. Finally, the authors identified 45 articles from Google Scholar and determined their relevance for the study using the same exclusion criteria: 16 of them were added to the final sample.

The selection process resulted in a final sample of 35 articles: 26 journal articles and 9 conference papers, published between 2010 and 2022. Table 2 presents the features of the sample in an overview that structures the selected articles according to research type (empirical or conceptual), then their purpose (to explore, to describe or to evaluate teaching and learning in sustainability-oriented Living Labs) and finally their approach (e.g. case study or literature review).

Data processing, coding and analysis

To answer the research question, the authors analyzed and synthesized the data based on the realist constructs "context," "intervention," "mechanism" and "outcome." These terms entail:

- context: descriptions of and reflections on Living Labs as socio-physical (learning) spaces;
- intervention: descriptions of and reflections on teaching activities and approaches;
- mechanism: descriptions of and reflections on learning activities and approaches; and
- outcome: descriptions of and reflections on learning outcomes.

To map those constructs, the constant comparison method for data analysis was applied (Onwuegbuzie *et al.*, 2012). The authors first gathered relevant data by reading each

Objective	Approach	Author	Origin
Research type: empirical			
Exploratory	Case studies (qualitative) and literature review	Jernsand (2019)	Sweden
	Case study: mixed-method	Rey-Garcia and Mato-Santiso (2020)	Spain
Descriptive	Action research	Dabaieh *et al.* (2017)	Egypt
		Dabaieh *et al.* (2018)	Egypt
		Masseck (2013)	Spain
	Case study	Carbone *et al.* (2019)	USA
		Holmberg *et al.* (2015)	Sweden
		König (2015)	Luxembourg
		Lindstrom and Middlecamp (2017)	USA
		McCormick and Kiss (2015)	UK
		Peterson (2018)	USA
		Roswag-Klinge *et al.* (2019)	Germany
		Roysen and Cruz (2020)	Brazil
		Thorpe and Rhodes (2018)	UK
	Case study: mixed method, qualitative and semi-quantitative	Beecroft (2018)	Germany
		Masseck (2017)	Spain
	Cross-case analysis	Eriksson *et al.* (2015)	Scandinavia
Evaluative	Case study	Bakırlıoğlu and McMahon (2021)	Ireland
		Evans *et al.* (2015)	UK
		Hector and Kohtala (2022)	Finland
		Holmén *et al.* (2021)	Sweden
		Illes and Kristianova (2022)	Slovakia
		Kohn Ra³dberg *et al.* (2020)	Sweden
		Krütli *et al.* (2018)	Germany
		Lake *et al.* (2016)	USA
		Larsson and Holmberg (2018)	Sweden
		Moosavi and Bush (2021)	Australia
		O'Brien *et al.* (2021)	USA
		Ramchunder and Ziegler (2021)	Singapore
		Trencher *et al.* (2015)	Japan
Research type: conceptual			
Exploratory	Literature review	Brundiers *et al.* (2010)	USA
	Review study	Zen (2017)	Malaysia
Descriptive	Case study	Caetano *et al.* (2018)	Portugal
		Felgueiras and Caetano (2018)	Portugal
	Literature review and survey	Gleeson *et al.* (2012)	Canada

Source: Authors' own creation/work

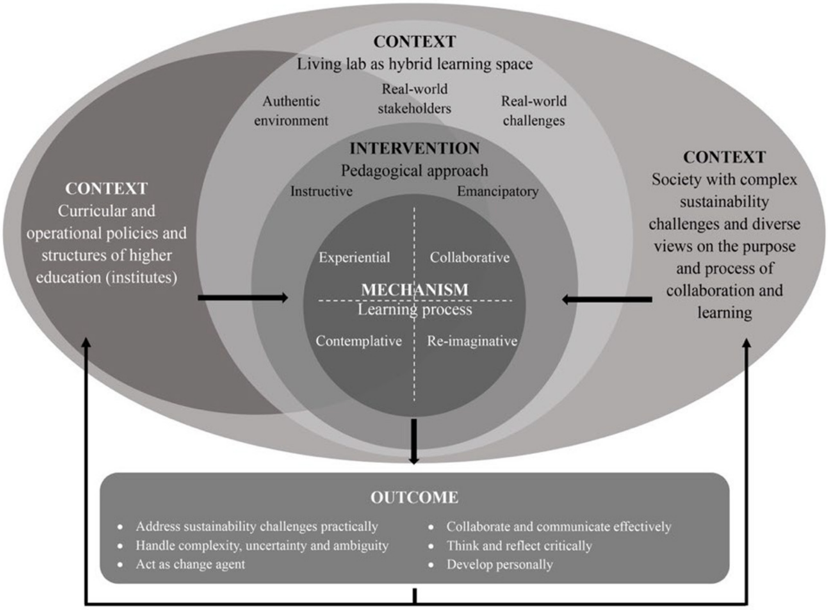
Table 2.
Features of selected articles

article entirely, marking relevant chunks of text and registering these chunks on a data extraction form (Booth *et al.*, 2022). For each of the realist constructs, the data (text chunks) from all selected publications were brought together in one file, using Microsoft Excel. Then the data were coded iteratively. First, by assigning open codes (descriptors) to each chunk of text and clustering these according to patterns of similarity through a process of comparing, revising and refining until categories were mutually exclusive (Onwuegbuzie *et al.*, 2012). Then by applying theoretical coding to connect emerging categories with existing theories and concepts. Relevant theoretical codes have been identified by reviewing literature about sustainability-oriented education, learning in

Living Labs and theories of teaching and learning referred to or discussed therein (Thornberg and Charmaz, 2014). The choice for constant comparison analysis revealed characteristics and challenges in an iterative way, consistent with the intended method and desired outcomes. As this process is interpretative, it ran the risk of bias or blind spots. To overcome this as much possible, the first author facilitated eight validating workshops with teachers and researchers involved in Living Labs at Rotterdam University of Applied Sciences to discuss the extent to which they recognized characteristics and challenges in their practice and to refine these if necessary.

Results

Based on the analysis described in the previous section, this study identified two types of sociophysical Living Lab contexts, two key pedagogical approaches as interventions, four different learning processes as (possible) mechanisms and six sustainability-related learning outcomes. Two main challenges were also identified. This section presents the results in five subsections. The first four describe the characteristics according to the four realist constructs: “context,” “intervention,” “mechanism” and “outcome.” References to articles analyzed for the realist review are presented in tables with some examples included in the text. References to sources that informed theoretical codification are included in the text. The last subsection presents the challenges for teaching and learning in Living Labs. In this sub-section, references to articles analyzed are included in the text. Figure 2 visualizes the realist constructs “context,” “intervention,” “mechanism” and “outcome” with their related characteristics and challenges.



Source: Authors’ own creation/work

Figure 2. Characteristics and challenges of teaching and learning in sustainability-oriented Living Labs within higher education

Context: characteristics of Living Lab contexts as hybrid learning spaces

Living Labs as socio-physical "contexts" within higher education are hybrid learning spaces at the interface of education and society (Bouw *et al.*, 2019). In such spaces, multiple stakeholders collaboratively work on solutions for (local) sustainability challenges by learning across the boundaries between disciplines, roles and structures (Vilsmaier and Lang, 2015). Analysis of the literature suggests that higher education institutes approach Living Labs as *authentic learning environments* and as *engagement with the real-world*. Table 3 presents these characteristics and their manifestations within higher education institutes.

Living Labs as authentic learning environments are situated on campus, in society or in between the two. A Living Lab *on campus* is integrated in the university community and allows students to work on sustainability challenges on their own campus such as possibilities for renewable energy (Caetano *et al.*, 2018) or sustainable building and construction (O'Brien *et al.*, 2021). A Living Lab *within society* is located outside the university campus, such as in a neighborhood or on a project site and engages students in sustainability issues in a local context, for example an urban farming initiative (McCormick and Kiss, 2015) or a climate responsive building project (Dabaieh *et al.*, 2017). A Living Lab *between campus and society*, for example, in a science park or urban hub, offers students and

Living Lab as hybrid learning space	Manifestation	References
As authentic learning environment	Living Lab on campus	Bakırlıoğlu and McMahon (2021); Brundiers *et al.* (2010); Caetano *et al.* (2018); Carbone *et al.* (2019); Dabaieh *et al.* (2018); Felgueiras and Caetano (2018); Hector and Kohtala (2022); Illes and Kristianova (2022); Jernsand (2019); Lindstrom and Middlecamp (2017); Masseck (2013); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021)
	Living Lab in society	Beecroft (2018); Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); Gleeson *et al.* (2012); Jernsand (2019); Krütli *et al.* (2018); Masseck (2017); McCormick and Kiss (2015); Moosavi and Bush (2021); Peterson (2018); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020)
	Living Lab between campus and society	Eriksson *et al.* (2015); Holmberg *et al.* (2015); Jernsand (2019); Kohn Ra^{3}dberg *et al.* (2020); Larsson and Holmberg (2018)
As engagement with the real world	Real-world challenges	Bakırlıoğlu and McMahon (2021); Brundiers *et al.* (2010); Dabaieh *et al.* (2017); Jernsand (2019); König (2015); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Lindstrom and Middlecamp (2017); Moosavi and Bush (2021); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021); Rey-Garcia and Mato-Santiso (2020); Roswag-Klinge *et al.* (2019); Thorpe and Rhodes (2018); Zen (2017)
	Real-world stakeholders	Beecroft (2018); Brundiers *et al.* (2010); Carbone *et al.* (2019); Dabaieh *et al.* (2017); Eriksson *et al.* (2015); Evans *et al.* (2015); Holmberg *et al.* (2015); Illes and Kristianova (2022); Jernsand (2019); König (2015); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Masseck (2017); McCormick and Kiss (2015); Peterson (2018); Rey-Garcia and Mato-Santiso (2020); Roswag-Klinge *et al.* (2019); Thorpe and Rhodes (2018); Trencher *et al.* (2015)

Source: Authors' own creation/work

Table 3.
Characteristics of Living Lab contexts

stakeholders a space at a distance from specific organizations or projects to provide a neutral environment (Kohn Ra³dberg *et al.*, 2020).

Living Labs as engagement with the real world enable students to work on *real-world challenges* that address the needs in a particular context, such as a project to promote low carbon mobility and transportation (Larsson and Holmberg, 2018) or a drought monitoring and preparedness program (Brundiers *et al.*, 2010). Such challenges are characterized by a certain level of complexity and uncertainty and turned into assignments such as design or research projects. Students also engage with *real-world stakeholders* from business, government, non-governmental organizations and civil society (Eriksson *et al.*, 2015; Evans *et al.*, 2015). Depending on the challenge, the stakeholders have a role as client, as partner or as user in their relation with students.

Interventions: characteristics of pedagogical approaches

Pedagogy refers to approaches for teaching and facilitation of learning (den Brok, 2018; Jackson and Barnett, 2019) and may have an *emancipatory* or *instructive* style. Table 4 presents these two approaches and their manifestations in Living Labs.

Pedagogical approach	Manifestation	References
Emancipatory	Facilitate action and experience	Beecroft (2018); Dabaieh *et al.* (2017); Gleeson *et al.* (2012); Jernsand (2019); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Moosavi and Bush (2021); O'Brien *et al.* (2021); Thorpe and Rhodes (2018)
	Facilitate collaboration with peers and/or real-world stakeholders	Bakırlıoğlu and McMahon (2021); Beecroft (2018); Brundiers *et al.* (2010); Caetano *et al.* (2018); Carbone *et al.* (2019); Dabaieh *et al.* (2017); Eriksson *et al.* (2015); Evans *et al.* (2015); Holmberg *et al.* (2015); Holmén *et al.* (2021); Illes and Kristianova (2022); Jernsand (2019); König (2015); Krütli *et al.* (2018); Lake *et al.* (2016); Moosavi and Bush (2021); Peterson (2018); Ramchunder and Ziegler (2021); Rey-Garcia and Mato-Santiso (2020); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020); Thorpe and Rhodes (2018); Trencher *et al.* (2015)
	Facilitate self-directed learning, freedom and choice	Bakırlıoğlu and McMahon (2021); Beecroft (2018); Carbone *et al.* (2019); Holmberg *et al.* (2015); Holmén *et al.* (2021); Jernsand (2019); Kohn Ra³dberg *et al.* (2020); König (2015); Krütli *et al.* (2018); Moosavi and Bush (2021); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021); Roswag-Klinge *et al.* (2019)
	Facilitate reflexivity	Holmberg *et al.* (2015); Holmén *et al.* (2021); Larsson and Holmberg (2018); Peterson (2018); Roysen and Cruz (2020)
Instructive	Give lectures and workshops	Bakırlıoğlu and McMahon (2021); Brundiers *et al.* (2010); Carbone *et al.* (2019); Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); König (2015); Krütli *et al.* (2018); Moosavi and Bush (2021); O'Brien *et al.* (2021); Rey-Garcia and Mato-Santiso (2020); Roysen and Cruz (2020)
	Supervise as expert	Carbone *et al.* (2019); Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); Krütli *et al.* (2018); Moosavi and Bush (2021)
	Provide instructions for assignments	Dabaieh *et al.* (2018); Moosavi and Bush (2021); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021)

Source: Authors' own creation/work

Table 4. Characteristics of pedagogical approaches

Emancipatory pedagogies acknowledge the complexity, uncertainty and ambiguity of sustainability challenges and generate space for reflexivity and choice, both freely made and self- or group-determined, with the intent to empower students to shape the direction of their collaborative work in the midst of challenges (Tassone *et al.*, 2022). In Living Labs, teachers in the role of supervisors apply these pedagogies by creating opportunities for students to collaboratively work on real-world challenges (Peterson, 2018) with activities for introspection on goals, values and responsibilities (Roysen and Cruz, 2020) and with possibilities for self-organization and self-determination (Beecroft, 2018).

Instructive pedagogies focus on transferring predetermined expert knowledge and skills with the intent to support students' collaborative work and its outcomes in a specific preestablished direction (Tassone *et al.*, 2022). In Living Labs, teachers in the role of instructors give shape to these pedagogies by giving lectures about relevant theories (Rey-Garcia and Mato-Santiso, 2020), by facilitating workshops about practical skills needed in the field (Roysen and Cruz, 2020), by supervising as experts (Illes and Kristianova, 2022) and by providing instructions for assignments that support students in working toward desired project outcomes that meet (technical) requirements of the field (O'Brien *et al.*, 2021) or respond to expectations of a client (Dabaieh *et al.*, 2018).

Mechanisms: characteristics of learning processes

Learning refers to the processes of developing new understanding, knowledge, skills, values, behaviors or attitudes (Illeris, 2018). The analysis identified four types of learning processes in sustainability-oriented Living Labs: *experiential, collaborative, contemplative and re-imaginative*. Table 5 presents these four types and their manifestations in Living Labs.

Experiential learning is about participating in authentic activities in a continuous cycle of experience, reflection, abstraction and action (Gaffney and O'Neil, 2019; Kolb and Kolb, 2017). In some Living Labs, students learn experientially by participating in *applied research projects*. In these projects, they investigate, for example, the ground water system (Gleeson *et al.*, 2012) or experiment with innovations, such as new technologies for sustainable urban transportation (Larsson and Holmberg, 2018) or renewable power generation (Carbone *et al.*, 2019; Masseck, 2013). In other labs, students learn experientially by engaging in authentic *hands-on tasks,* such as constructing a small-scale refugee shelter with climate responsive building materials (Dabaieh *et al.*, 2018) or clean-up tasks in a local neighborhood (Peterson, 2018). To learn from such experiences through reflection and abstraction, students take theoretical courses or workshops (Dabaieh *et al.*, 2017), reflectively discuss their work with experts and peers (Beecroft, 2018) or present proposed solutions to representatives from professional practice or society (Illes and Kristianova, 2022).

Collaborative learning is about working as a team toward a common goal by connecting diverse practices and perspectives and by navigating and reconciling differences and contradictions (Bakker and Akkerman, 2019; Davidson and Major, 2014). In Living Labs, students learn collaboratively *with peers from diverse disciplines*. They work in small groups on proposals for challenges such as sustainable waste management (Lindstrom and Middlecamp, 2017) or responsible tourism (Jernsand, 2019), by integrating similarities and differences through discussion, reflection and reconciliation. When *stakeholders from professional practice or society* join their team, students connect academic knowledge and skills to everyday (professional) practice by taking into account stakeholders' knowledge and experiences. They may team up with community members' initiatives to revitalize an urban neighborhood (Lake *et al.*, 2016), collaborate with societal stakeholders to renovate existing appartement buildings (McCormick and Kiss, 2015) or regularly meet up with stakeholders to present and discuss ideas (Thorpe and Rhodes, 2018).

Table 5. Characteristics of learning processes

Learning process	Manifestation	References
Experiential	Conduct applied research	Beecroft (2018); Carbone *et al.* (2019); Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); Eriksson *et al.* (2015); Gleeson *et al.* (2012); Hector and Kohtala (2022); Illes and Kristianova (2022); Jernsand (2019); Kohn Ra^{3}dberg *et al.* (2020); König (2015); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Lindstrom and Middlecamp (2017); Masseck (2013); McCormick and Kiss (2015); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021); Thorpe and Rhodes (2018); Trencher *et al.* (2015)
	Engage in hands-on tasks	Dabaieh *et al.* (2018); O'Brien *et al.* (2021); Peterson (2018); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020)
Collaborative	Collaborate with students from diverse disciplines	Bakırlıoğlu and McMahon (2021); Caetano *et al.* (2018); Carbone *et al.* (2019); Eriksson *et al.* (2015); Evans *et al.* (2015); Jernsand (2019); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Lindstrom and Middlecamp (2017); Moosavi and Bush (2021); Ramchunder and Ziegler (2021); Rey-Garcia and Mato-Santiso (2020); Roswag-Klinge *et al.* (2019); Thorpe and Rhodes (2018)
	Collaborate with stakeholders from professional practice and society	Beecroft (2018); Brundiers *et al.* (2010); Dabaieh *et al.* (2017); Eriksson *et al.* (2015); Evans *et al.* (2015); Holmberg *et al.* (2015); Jernsand (2019); Kohn Ra^{3}dberg *et al.* (2020); König (2015); Krütli *et al.* (2018); Lake *et al.* (2016); Larsson and Holmberg (2018); Masseck (2017); McCormick and Kiss (2015); Moosavi and Bush (2021); Peterson (2018); Rey-Garcia and Mato-Santiso (2020); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020); Thorpe and Rhodes (2018); Trencher *et al.* (2015)
Contemplative	Individual introspection	Holmberg *et al.* (2015); Holmén *et al.* (2021); Lake *et al.* (2016); Larsson and Holmberg (2018); Peterson (2018); Roysen and Cruz (2020)
	Collective introspection	Holmén *et al.* (2021); Peterson (2018); Roysen and Cruz (2020)
Reimaginative	Explore possible alternatives	Holmén *et al.* (2021); Lake *et al.* (2016); Roysen and Cruz (2020)
	Imagine possible futures	Holmberg *et al.* (2015); Kohn Rådberg *et al.* (2020); Larsson and Holmberg (2018)

Source: Authors' own creation/work

Contemplative learning is about engaging deeply with a challenge by exploring personal values and motivations toward it with practices that nurture self-awareness, trusting relations with others and an ethical connection with the world (Barbezat and Bush, 2014; Zajonc, 2013). With *individual introspection* through, e.g. journaling or reflective paper writing, students explore their own goals, values and responsibilities related to, for example, climate change (Holmberg *et al.*, 2015) or sustainable food production (Roysen and Cruz, 2020). With *collective introspection*, e.g. daily opening circles or story-telling exercises, students share their goals, values or emotions with peers and supervisors and explore possibilities for togetherness and shared responsibility for the collective learning space (Holmén *et al.*, 2021).

Re-imaginative learning takes a post-critical perspective and is about learning which goes beyond merely critiquing the (unsustainable) status quo by imagining a desired (sustainable) future and taking (collective) action toward such a future (Hodgson *et al.*, 2018; Wortmann, 2020). In Living Labs, students *explore possible alternatives*, for example, by participating in practices other than business-as-usual, such as natural waste processing

(Roysen and Cruz, 2020), or by collaborating with marginalized groups in urban planning processes (Lake *et al.*, 2016). In other labs, they use a back-casting approach to *imagine possible futures* of, for example, water safety or responsible recreation (Larsson and Holmberg, 2018); they turn imagination into possibilities for action by investigating what the change toward an imagined future would require from existing systems and routines, from their own capabilities and beliefs, and from their collaboration and interaction with others (Roysen and Cruz, 2020).

Outcomes: characteristics of learning outcomes

Six sustainability-related learning outcomes emerged from the analysis, i.e. capacities students develop by learning in Living Labs: *address sustainability challenges practically; handle complexity, uncertainty and ambiguity; act as change agent; collaborate and communicate effectively; think and reflect critically;* and *develop personally*. Table 6 presents these capacities together with the socio-physical characteristics of Living Labs, the pedagogical approaches and the learning processes that are mentioned or described in connection with these capacities, according to the realistic constructs of "context," "intervention" and "mechanism".

Learning in Living Labs enables students to increase their (general) capacity to *address sustainability challenges practically*. Through for instance experiential and collaborative learning in design projects, theoretical lectures and supervision by experts, students learn how to develop practical solutions while taking into account the complexity and contextuality of a challenge. This capacity is, for example, reflected in students' work on prototypes for climate responsive buildings (Dabaieh *et al.*, 2017) or on a tool kit to reduce food waste (Bakırlıoğlu and McMahon, 2021).

Also, learning in Living Labs allows students to develop their capacity to *handle complexity, uncertainty and ambiguity*. For example, collaborative project-based learning, self-organized working and facilitated research seminars enable students to learn how to work iteratively across different angles and features, as well as to become competent in exploring, discussing and integrating diverse (and sometimes contradicting) perspectives. This capacity becomes visible in students' ideas for democratizing renewable energy (König, 2015) or their ability to work with different and sometimes conflicting viewpoints (Moosavi and Bush, 2021), among other examples documented in the literature.

In addition, learning in Living Labs empowers students to *act as change agents*. By performing activities like collaborating with residents, experiencing alternative eco-responsible practices and taking workshops about grassroots innovations, students learn to denormalize taken-for-granted practices, trust alternative methods and address challenges unconventionally. This capacity manifests itself, for example, when students apply low-tech building materials (Dabaieh *et al.*, 2018) or collaborate with community activists to promote socially just urban planning (Peterson, 2018).

Furthermore, learning in Living Labs enables students to develop their capacity to *collaborate and communicate effectively*. In collaborative experiments on campus or partnerships with local residents, students learn how to organize teamwork, deal with different perspectives and views and communicate ideas with diverse audiences. Students' capacity comes forth when they work as a team (Zen, 2017), deal with difficult and frustrating team processes (Hector and Kohtala, 2022), present their work to different audiences (Illes and Kristianova, 2022) or collaborate with residents on equitable local services (Thorpe and Rhodes, 2018).

Learning in Living Labs also enables students to increase their capacity to *think and reflect critically*. By participating and collaborating in grassroots sustainability initiatives (Jernsand, 2019), engaging in introspective practices (Roysen and Cruz, 2020) or imagining

Realist construct	Enablers	References
***Outcome**: address sustainability challenges practically*		
Context	Authentic learning environment	Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); Krütli *et al.* (2018); Masseck (2013); Ramchunder and Ziegler (2021)
	Engagement with the real world	Brundiers *et al.* (2021); Dabaieh *et al.* (2018); Jernsand (2019); Krütli *et al.* (2018); Larsson and Holmberg (2018); Moosavi and Bush (2021); Zen (2017)
Intervention	Emancipatory pedagogy	Bakırlıoğlu and McMahon (2021); Dabaieh *et al.* (2018); Felgueiras and Caetano (2018); Hector and Kohtala (2022); Holmberg *et al.* (2015); Holmén *et al.* (2021); Lake *et al.* (2016); Ramchunder and Ziegler (2021)
	Instructive pedagogy	Bakırlıoğlu and McMahon (2021); Dabaieh *et al.* (2018); Lake *et al.* (2016); Moosavi and Bush (2021)
Mechanism	Experiential learning	Brundiers *et al.* (2010); Carbone *et al.* (2019); Dabaieh *et al.* (2018); Dabaieh *et al.* (2017); Hector and Kohtala (2022); Holmberg *et al.* (2015); Lake *et al.* (2016); Moosavi and Bush (2021); O'Brien *et al.* (2021); Ramchunder and Ziegler (2021)
	Collaborative learning	Bakırlıoğlu and McMahon (2021); Felgueiras and Caetano (2018); Holmén *et al.* (2021); Lake *et al.* (2016); Moosavi and Bush (2021); Ramchunder and Ziegler (2021)
***Outcomes**: handle complexity, uncertainty and ambiguity*		
Context	Authentic learning environment	Brundiers *et al.* (2010); McCormick and Kiss (2015)
	Engagement with the real world	Carbone *et al.* (2019); Lake *et al.* (2016)
Intervention	Emancipatory pedagogy	Carbone *et al.* (2019); Holmberg *et al.* (2015); Lake *et al.* (2016); Larsson and Holmberg (2018)
	Instructive pedagogy	Carbone *et al.* (2019)
Mechanism	Experiential learning	Brundiers *et al.* (2010); Carbone *et al.* (2019); Holmberg *et al.* (2015); Lake *et al.* (2016); Larsson and Holmberg (2018); McCormick and Kiss (2015)
	Collaborative learning	Bakırlıoğlu and McMahon (2021); König (2015); Lake *et al.* (2016); Moosavi and Bush (2021)
***Outcomes**: act as change agent*		
Context	Authentic learning environment	Holmberg *et al.* (2015); Lindstrom and Middlecamp (2017); McCormick and Kiss (2015); Peterson (2018); Roysen and Cruz (2020)
	Engagement with the real world	Holmberg *et al.* (2015)
Intervention	Emancipatory pedagogy	Dabaieh *et al.* (2018); Holmberg *et al.* (2015); Holmén *et al.* (2021); Lindstrom and Middlecamp (2017); Peterson (2018); Roysen and Cruz (2020)
	Instructive pedagogy	Roysen and Cruz (2020)
Mechanism	Experiential learning	Dabaieh *et al.* (2018); Peterson (2018)
	Collaborative learning	Lake *et al.* (2016)
	Re-imaginative learning	Holmén *et al.* (2021); Roysen and Cruz (2020)
***Outcomes**: collaborate and communicate effectively*		
Context	Engagement with the real world	Brundiers *et al.* (2010); Dabaieh *et al.* (2018); Holmén *et al.* (2021); Larsson and Holmberg (2018); Roysen and Cruz (2020); Zen (2017)
Intervention	Emancipatory pedagogy	Brundiers *et al.* (2010); Illes and Kristianova (2022); Lake *et al.* (2016); Roysen and Cruz (2020); Zen (2017)

(*continued*)

Table 6.
Characteristics of learning outcomes

Realist construct	Enablers	References
Mechanism	Experiential learning	Brundiers *et al.* (2010); Hector and Kohtala (2022)
	Collaborative learning	Brundiers *et al.* (2010); Hector and Kohtala (2022); Lake *et al.* (2016); Masseck (2013); Thorpe and Rhodes (2018)
Outcomes*: think and reflect critically*		
Context	Engagement with the real world	Jernsand (2019); Lake *et al.* (2016)
Intervention	Emancipatory pedagogy	Gleeson *et al.* (2012); Hector and Kohtala (2022); Holmén *et al.* (2021); Jernsand (2019); König (2015); Lake *et al.* (2016); O'Brien *et al.* (2021)
Mechanism	Experiential learning	Carbone *et al.* (2019); Gleeson *et al.* (2012); Hector and Kohtala (2022); König (2015); O'Brien *et al.* (2021)
	Collaborative learning	Jernsand (2019); Lake *et al.* (2016)
	Contemplative learning	Holmén *et al.* (2021); Roysen and Cruz (2020)
	Re-imaginative learning	Holmén *et al.* (2021)
Outcomes*: develop personally*		
Context	Authentic learning environment	Dabaieh *et al.* (2018); Ramchunder and Ziegler (2021); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020)
	Engagement with the real world	Kohn Ra³dberg *et al.* (2020); Larsson and Holmberg (2018); Moosavi and Bush (2021); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020); Thorpe and Rhodes (2018)
Intervention	Emancipatory pedagogy	Lake *et al.* (2016); Larsson and Holmberg (2018); Ramchunder and Ziegler (2021); Roysen and Cruz (2020)
Mechanism	Experiential learning	Dabaieh *et al.* (2018); Holmberg *et al.* (2015); Ramchunder and Ziegler (2021); Roswag-Klinge *et al.* (2019); Roysen and Cruz (2020)
	Collaborative learning	Hector and Kohtala (2022); Lake *et al.* (2016); Larsson and Holmberg (2018); Moosavi and Bush (2021); Ramchunder and Ziegler (2021); Roswag-Klinge *et al.* (2019); Thorpe and Rhodes (2018)
	Contemplative learning	Roysen and Cruz (2020)

Table 6.

Source: Authors' own creation/work

possible futures (Holmén *et al.*, 2021), students learn to engage with socio-ecological issues ethically and to question the desirability of actions from the perspective of social and environmental impact. Students' capacity becomes visible in their work through, for example, more socially aware action plans (Lake *et al.*, 2016), or knowledge of marginalized issues and perspectives (Hector and Kohtala, 2022).

Finally, learning in Living Labs enables students to *develop personally*. This can be through nature-based collaborative experiences, student-led discussions or introspective storytelling, all of which help students develop self-confidence to pursue ideas (Roswag-Klinge *et al.*, 2019), a sense of care for other people and the environment (Ramchunder and Ziegler, 2021) and open-mindedness toward other perspectives (Lake *et al.*, 2016).

Challenges

This section describes two challenges identified through the literature analysis. The first challenge relates to the norms, policies and practices of higher education institutes, and the second to the intentions, expectations and perspectives of stakeholders in a Living Lab.

First, the analysis suggests that current institutional norms, policies and practices of higher education seem to restrain rather than to encourage sustainability-oriented teaching and learning in Living Labs. With their focus on transferring knowledge and fostering domain-specific learning, higher education curricula struggle or might even fail to address the complexity, uncertainty and ambiguity of the sustainability challenges society currently faces (e.g. Felgueiras and Caetano, 2018). The focus on prioritizing efficiency and productivity through intensive course schedules, rigid assessment regulations and the accumulation of study credits, among other factors, makes it difficult for students to engage in sustainability-oriented learning processes, for example, by taking charge of their own learning, practicing introspection and contemplation or taking time for iterative design processes (Hector and Kohtala, 2022). In short, the analysis of literature suggests that, if the aim of teaching and learning in Living Labs is to support sustainability-oriented transformative learning by students, then higher education faces the challenge of reconsidering and transforming its institutional norms, policies and practices to support that aim.

Second, the analysis of literature indicates that the intentions, expectations and perspectives of stakeholders in Living Labs, i.e. teachers, students and societal stakeholders, do not necessarily support sustainability-oriented learning. Teachers may resist or even reject alternative approaches, such as experiential and collaborative ones that connect science and society, as they do not see how these could add to students' knowledge and understanding (e.g. Dabaieh *et al.*, 2017). In turn, students sometimes perceive these approaches as a sign to take a project not entirely seriously (Beecroft, 2018), or to act as mere problem-solvers, rather than as facilitators of change who address challenges critically and collaboratively with stakeholders (Holmén *et al.*, 2021). On their side, stakeholders can easily envision their engagement in a Living Lab as an opportunity for assigning (predefined) tasks to students (e.g. Brundiers *et al.*, 2010), rather than as an opportunity for collaboration with academia. In short, the analysis of literature suggests that if the aim of teaching and learning in Living Labs is to support students in developing the capacity to cope with sustainability challenges, then higher education faces the challenge of encouraging participants to connect, to cross boundaries and to engage in a genuine collaborative endeavor at the interface of science and society (e.g. Roysen and Cruz, 2020).

Discussion

The aim of this study was to bring together scattered research about characteristics and challenges of teaching and learning in Living Labs in higher education and to explore their potential for supporting students' sustainability-oriented transformative learning. In this section, we reflect on the findings that emerged from this study, discuss their implications for both practice and research and suggest possible avenues for future research.

With its realist approach, this study was able to generate initial insights into teaching approaches, learning processes and learning outcomes in sustainability-oriented Living Labs. Consistent with the results of other studies, the findings suggest that teaching and learning in Living Labs has the potential to support students in developing the capacity to tackle complex challenges and promote transformation toward sustainability. First, with regard to the pedagogical approaches, the findings of this study indicate that both *instructive* and *emancipatory* approaches support sustainability-oriented learning. This is in line with other studies, for example, Tassone *et al.* (2022), who demonstrated the value of combining both pedagogies to enable students to deal with complex sustainability challenges, and to shape their own path in the midst of such challenges. Second, with respect to the learning processes, the findings suggest that all four learning processes, i.e. *experiential*, *collaborative*, *contemplative* and *re-imaginative*, support sustainability-oriented learning, which is consistent with other studies. For example, Gaffney and O'Neil (2019) explained that *experiential learning* allows students to enhance their understanding of complex challenges and change their perspective on how to tackle them. Several other studies about sustainability-oriented learning confirm the potential of the three other learning processes, i.e. *collaborative* (e.g. Veltman *et al.*, 2019), *contemplative* (e.g. Goralnik and Marcus, 2020) and *re-imaginative learning* (e.g. Sharp *et al.*, 2021). Third, the learning outcomes identified in this study are consistent with other studies presenting sustainability competences, such as problem-solving, system-thinking (Brundiers *et al.*, 2021), critical thinking, communication and collaboration (Lozano *et al.*, 2017) and taking responsibility for other people and the environment (Cebrián Bernat *et al.*, 2019).

Despite the potential described above, challenges emerging from the literature also raise questions about the extent to which teaching and learning in Living Labs can fully enable students to develop the capacity to promote transformation toward sustainability.

Living Labs as learning environments for higher education students are part of higher education institutes. While the aim of a lab may be to promote transformation toward sustainability, teaching and learning therein often takes place in an institutional context characterized by norms, policies and practices that do not necessarily support that aim. Higher education is a complex (institutional) ecosystem in which teaching and learning are influenced by (but may also influence) the values, processes, resources and ultimately the policy and practices of a particular higher education institute (Jackson, 2019; McCrory *et al.*, 2022). This raises an uncertainty about the extent to which Living Labs can live up to their promise to support sustainability-oriented transformative learning by students when existing higher education institutional policies and structures are kept in place.

Living Labs are also learning spaces at the interface of education and society. In these learning spaces, stakeholders from education, science and society come together around a common challenge bringing their own background, knowledge, intentions and expectations. In essence, this is what Jackson and Barnett (2019) and Wals (2019) described as a learning ecology. In a learning ecology, participants from various backgrounds use diverse forms of learning and collaboration to create new meanings and understandings of the world and of their own ways of thinking, being and acting in it. However, even though a learning ecology brings participants together, common ground for the purpose and process of collaboration and co-learning between academia and society is not self-evident. This again raises an uncertainty about the capacity of Living Labs to live up to their potential to support sustainability-oriented transformative learning by students when a willingness to cross boundaries and a common ground for sustainability-oriented collaboration and co-learning are insufficient or absent.

In conclusion, this study shows the potential of teaching and learning in sustainability-oriented Living Labs, and it raises questions in relation to the challenges involved. Approaching a Living Lab as a learning ecology that is embedded in the wider ecosystem of a higher education institute can be a way forward for both practice and research. For practice, doing so implies that harvesting the transformative potential of teaching and learning in sustainability-oriented Living Labs can benefit from a more systemic whole-institution approach, i.e. continuous individual and institutional learning to mainstream sustainability as a fundamental principle for all activities of a higher education institute (Holst, 2023). Hence, higher education institutes need to "walk the talk" of sustainability and connect their external orientation of educating about and for sustainability with an internal focus of being (becoming) sustainable. This means coherently redesigning the purpose and practices of education, teaching and learning; of collaboration and co-learning with societal stakeholders; and of operations, management and control (Wamsler *et al.*, 2021). As this is a context-specific pathway for each higher education institute (Holst, 2023), it requires approaches that are relational in terms of connecting to others and to the environment; responsible in terms of addressing sustainability in a relevant and equitable way; responsive in terms of dealing with sustainability as an ongoing (learning) process characterized by continuous change and uncertainty; and emancipatory in terms of fostering self-determination, agency and an ethic of care for identifying challenges and exploring ways for addressing them (Wals, 2019).

For research, a learning ecology and ecosystem approach implies that developing a set of scientifically grounded guiding principles for sustainability-oriented teaching and learning in Living Labs calls for a more systemic understanding of where, when, how and why teaching and learning in Living Labs fosters (or hinders) sustainability-oriented transformative learning (Tassone *et al.*, 2023). Hence, future studies should empirically examine characteristics of and experiences with education in Living Labs by focusing on the interplay between the Living Lab as a hybrid learning space, the approaches for teaching and learning used therein, the practices that foster collaboration and co-learning with societal stakeholders and the policies and structures of the higher education institute in which the Living Lab is embedded. By studying this in multiple Living Labs, scattered findings can be brought together into a set of scientifically grounded guiding principles for designing sustainability-oriented education in Living Labs and promoting deeper changes within the higher education institute (Kandiko Howson and Kingsbury, 2023).

The characteristics and challenges that emerged from this study offer educators a set of guiding principles for making scientifically-grounded informed choices for teaching and learning in Living Labs (Katikas and Sotiriou, 2023). Educators can, for example, draw on emancipatory pedagogical interventions if they aim to promote collaborative or experiential learning processes and choose instructive pedagogies if they need to provide clearer directions for supporting students in achieving an intended result. However, the authors also acknowledge the study's limitations. The sample only included literature about Living Labs in higher education and did not consider possibly relevant articles outside education, for example, Living Labs in urban governance or neighborhood development. Also, the sample was confined to literature written in English, excluding possibly relevant articles in other languages. In addition, the majority of the articles are about Living Labs in Europe or the USA, i.e. a Western context. The results may therefore be biased toward a Western perspective on teaching and learning, excluding non-Western views and perspectives. Finally, although this study sheds light on the potential of education in Living Labs for fostering sustainability-oriented transformative learning, further research can help to enrich and deepen this study's findings by empirically examining where, when, how and why developing the capacity to tackle complex challenges and promote transformation toward sustainability is supported (or hindered) by the interplay between teaching and learning in Living Labs, collaboration and co-learning at the interface of education and society and higher education institutional policies and structures.

Conclusion

As far as the authors know, this is the first study that brings together results from previous research into a comprehensive description of characteristics and challenges of teaching and learning in Living Labs as sustainability-oriented learning spaces in higher education. It shows that teaching and learning in Living Labs has the potential to foster sustainability-oriented transformative learning. It also shows that there is a need for a common ground for collaboration between education and society; and for institutional policies, structures and practices which embrace the orientation toward sustainability. Approaching a Living Lab as a learning ecology embedded in the ecosystem of a higher education institute can be a way forward for both educational practice and research. Further research could enrich and deepen the findings of the current work by empirically examining when, how and why certain characteristics of Living Labs, as identified in this study, could support transformative teaching and learning toward sustainability and empower higher education students to find pathways toward a sustainable future.

References

Backman, M., Pitt, H., Marsden, T., Mehmood, A. and Mathijs, E. (2019), "Experiential approaches to sustainability education: towards learning landscapes", *International Journal of Sustainability in Higher Education*, Vol. 20 No. 1, pp. 139-156, doi: 10.1108/IJSHE-06-2018-0109.

Bakırlıoğlu, Y. and McMahon, M. (2021), "Co-learning for sustainable design: the case of a circular design collaborative project in Ireland", *Journal of Cleaner Production*, Vol. 279, p. 123474, doi: 10.1016/j.jclepro.2020.123474.

Bakker, A. and Akkerman, S. (2019), "The learning potential of boundary crossing in the vocational curriculum", in Guile, D. and Unwin, L. (Eds), *The Wiley Handbook of Vocational Education and Training*, John Wiley and Sons, Hoboken, NJ, USA, pp. 349-372, doi: 10.1002/9781119098713.ch18.

Balsiger, J., Förster, R., Mader, C., Nagel, U., Sironi, H., Wilhelm, S. and Zimmermann, A.B. (2017), "Transformative learning and education for sustainable development", *GAIA – Ecological Perspectives for Science and Society*, Vol. 26 No. 4, pp. 357-359, doi: 10.14512/gaia.26.4.15.

Barbezat, D.P. and Bush, M. (2014), *Contemplative Practices in Higher Education: powerful Methods to Transform Teaching and Learning*, Jossey Bass, San Fransisco.

Beecroft, R. (2018), "Embedding higher education into a real-world lab: a process-oriented analysis of six transdisciplinary project courses", *Sustainability*, Vol. 10 No. 10, p. 3798, doi: 10.3390/su10103798.

Booth, A., Sutton, A., Clowes, M. and Martyn-St James, M. (2022), *Systematic Approaches to a Successful Literature Review*, Sage, Los Angeles.

Bouw, E., Zitter, I. and De Bruijn, E. (2019), "Characteristics of learning environments at the boundary between school and work–a literature review", *Educational Research Review*, Vol. 26 No. 1, pp. 1-15.

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N. and Jarchow, M. (2021), "Key competencies in sustainability in higher education—toward an agreed-upon reference framework", *Sustainability Science*, Vol. 16 No. 1, pp. 13-29, doi: 10.1007/s11625-020-00838-2.

Brundiers, K., Wiek, A. and Redman, C.L. (2010), "Real-world learning opportunities in sustainability: from classroom into the real world", *International Journal of Sustainability in Higher Education*, Vol. 11 No. 4, pp. 308-324, doi: 10.1108/14676371011077540.

Caetano, N.S., Carvalho, R.R., Franco, F.R., Afonso, C.A.R. and Felgueiras, C. (2018), "Sustainable engineering labs - a Portuguese perspective", *Energy Procedia*, Vol. 153, pp. 455-460, doi: 10.1016/j.egypro.2018.10.077.

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martin-López, B., Hondrila, K., König, A., von Wehrden, H., Schäpke, N. and Laubichler, M. (2021), "A pluralistic and integrated approach to action-oriented knowledge for sustainability", *Nature Sustainability*, Vol. 4 No. 2, pp. 93-100, doi: 10.1038/s41893-020-00616-z.

Carbone, I., Boulton, K., Nathan, S. and Gould, B. (2019), "Student-designed greenhouse for sustainability competencies", *Journal of Sustainability Education*, Vol. 21.

Cebrián Bernat, G., Segalàs Coral, J. and Hernández Gómez, M. (2019), "Assessment of sustainability competencies: a literature review and future pathways for ESD research and practice", *Central European Review of Economics and Management*, Vol. 3 No. 3, pp. 19-44, doi: 10.29015/cerem.664.

Dabaieh, M., El Mahdy, D. and Maguid, D. (2018), "Living labs as a pedagogical teaching tool for green building design and construction in hot arid regions", *Archnet-IJAR: International Journal of Architectural Research*, Vol. 12 No. 1, pp. 338-355.

Dabaieh, M., Lashin, M. and Elbably, A. (2017), "Going green in architectural education: an urban living lab experiment for a graduation green design studio in Saint Catherine, Egypt", *Solar Energy*, Vol. 144, pp. 356-366, doi: 10.1016/j.solener.2017.01.010.

Davidson, N. and Major, C.H. (2014), "Boundary crossings: cooperative learning, collaborative learning, and problem-based learning", *Journal on Excellence in College Teaching*, Vol. 25 Nos 3/4, pp. 7-55.

Den Brok, P. (2018), *Cultivating the Growth of Life-Science Graduates: On the Role of Educational Ecosystems*, Wageningen University and Research, Wageningen, doi: 10.18174/458920.

Desha, C., Caldera, S. and Hutchinson, D. (2021), "Exploring the development of context appreciation in coursework that targets problem-solving for sustainable development", *International Journal of Sustainability in Higher Education*, Vol. 22 No. 5, pp. 1186-1224, doi: 10.1108/IJSHE-01-2020-0024.

Disterheft, A., Caeiro, S., Azeiteiro, U.M. and Leal Filho, W. (2013), "Sustainability science and education for sustainable development in universities: a way for transition", in Caeiro, S., Filho, W.L., Jabbour, C. and Azeiteiro, U.M. (Eds), *Sustainability Assessment Tools in Higher Education Institutions: Mapping Trends and Good Practices Around the World*, Springer International Publishing, Cham, pp. 3-27, doi: 10.1007/978-3-319-02375-5_1.

Erickson, F. and Gutierrez, K. (2002), "Comment: culture, rigor, and science in educational research", *Educational Researcher*, Vol. 31 No. 8, pp. 21-24, doi: 10.3102/0013189X031008021.

Eriksson, R., Nenonen, S., Junghans, A., Nielsen, S.B. and Lindahl, G. (2015), "Nordic campus retrofitting concepts–scalable practices", *Procedia Economics and Finance*, Vol. 21, pp. 329-336, doi: 10.1016/S2212-5671(15)00184-7.

European Commission (2022a), *On a European Strategy for Universities*, European Commission, Strasbourg.

European Commission (2022b), *On Building Bridges for Effective European Higher Education Cooperation*, European Commission, Strasbourg.

European Commission (2023), "New European Bauhaus progress report", European Commission, Brussels.

Evans, J., Jones, R., Karvonen, A., Millard, L. and Wendler, J. (2015), "Living labs and co-production: university campuses as platforms for sustainability science", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 1-6, doi: 10.1016/j.cosust.2015.06.005.

Favaloro, T., Ball, T. and Lipschutz, R.D. (2019), "Mind the gap! Developing the campus as a living lab for student experiential learning in sustainability", in Leal Filho, W. and Bardi, U. (Eds), *Sustainability on University Campuses: learning, Skills Building and Best Practices*, Springer, Cham, pp. 91-113.

Felgueiras, M. and Caetano, N. (2018), "ZELab: planning a living lab to educate modern engineering professionals", Paper presented at the Proceedings of the Sixth International Conference on Technological Ecosystems for Enhancing Multiculturality, Salamanca, Spain, doi: 10.1145/3284179.3284270,10.1145/3284179.3284270.

Gaffney, J.L. and O'Neil, J.K. (2019), "Experiential learning and sustainable development", in Leal Filho, W. (Ed.), *Encyclopedia of Sustainability in Higher Education*, Springer, Cham, doi: 10.1007/978-3-319-63951-2_348-1.

Gleeson, T., Allen, D.M. and Ferguson, G. (2012), "Teaching hydrogeology: a review of current practice", *Hydrology and Earth System Sciences*, Vol. 16 No. 7, pp. 2159-2168, doi: 10.5194/hess-16-2159-2012.

Goralnik, L. and Marcus, S. (2020), "Resilient learners, learning resilience: contemplative practice in the sustainability classroom", *New Directions for Teaching and Learning*, Vol. 2020 No. 161, pp. 83-99, doi: 10.1002/tl.20375.

Hector, P. and Kohtala, C. (2022), "Experimenting with sustainability education: the case of a student-driven campus initiative in Finland", *Local Environment*, Vol. 27 No. 12, pp. 1415-1430, doi: 10.1080/13549839.2021.1891033.

Hodgson, N., Vlieghe, J. and Zamojski, P. (2018), "Education and the love for the world: articulating a post-critical educational philosophy", *Foro de Educación*, Vol. 16 No. 24, pp. 7-20, doi: http://dx.doi.org/10.14516/fde.576.

Holmberg, J., Andersson, D. and Larsson, J. (2015), "Challenge lab: a transformative and integrative approach for sustainability transitions", The International Sustainability Transitions Conference (IST 2015), pp. 1-18.

Holmén, J., Adawi, T. and Holmberg, J. (2021), "Student-led sustainability transformations: employing realist evaluation to open the black box of learning in a challenge lab curriculum", *International Journal of Sustainability in Higher Education*, Vol. 22 No. 8, pp. 1-24, doi: 10.1108/IJSHE-06-2020-0230.

Holst, J. (2023), "Towards coherence on sustainability in education: a systematic review of whole institution approaches", *Sustainability Science*, Vol. 18 No. 2, pp. 1015-1030, doi: 10.1007/s11625-022-01226-8.

Illeris, K. (2018), "A comprehensive understanding of human learning", in Illeris, K. (Ed.), *Contemporary Theories of Learning*, Routledge, London, pp. 7-20, doi: 10.4324/9781315147277.

Illes, J. and Kristianova, K. (2022), "Architectural education: design studio as living lab", 16th International Technology, Education and Development Conference (INTED2022), IATED Academy, Online, pp. 2259-2264, doi: 10.21125/inted.2022.

IPCC (2022), "Climate change 2022: impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change", in Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., Okem, A. and Rama, B. (Eds), Cambridge, UK and New York, NY, p. 3056, doi: 10.1017/9781009325844.

Jackson, N. and Barnett, R. (2019), "Introduction: steps to ecologies for learning and practice", in Barnett, R. and Jackson, N. (Eds), *Ecologies for Learning and Practice: Emerging Ideas, Sightings, and Possibilities*, Routledge, London, pp. 1-16.

Jackson, N.J. (2019), "Ecologies for learning and practice in higher education ecosystems", in Barnett, R. and Jackson, N. (Eds), *Ecologies for Learning and Practice: Emerging Ideas, Sightings, and Possibilities*, Routledge, London, pp. 81-96.

Jernsand, E.M. (2019), "Student living labs as innovation arenas for sustainable tourism", *Tourism Recreation Research*, Vol. 44 No. 3, pp. 337-347, doi: 10.1080/02508281.2019.1613299.

Kandiko Howson, C. and Kingsbury, M. (2023), "Curriculum change as transformational learning", *Teaching in Higher Education*, Vol. 28 No. 8, pp. 1847-1866, doi: 10.1080/13562517.2021.1940923.

Katikas, L. and Sotiriou, S. (2023), "Schools as living labs for the new European Bauhaus", *Universal Access in the Information Society*, pp. 1-12, doi: 10.1007/s10209-023-01044-4.

Kohn Ra³dberg, K., Lundqvist, U., Malmqvist, J. and Hagvall Svensson, O. (2020), "From CDIO to challenge-based learning experiences - expanding student learning as well as societal impact?", *European Journal of Engineering Education*, Vol. 45 No. 1, pp. 22-37, doi: 10.1080/03043797.2018.1441265.

Kolb, A.Y. and Kolb, D.A. (2017), "Experiential learning theory as a guide for experiential educators in higher education", *Experiential Learning and Teaching in Higher Education*, Vol. 1 No. 1, pp. 7-44, doi: 10.46787/elthe.v1i1.3362.

König, A. (2015), "Towards systemic change: on the co-creation and evaluation of a study programme in transformative sustainability science with stakeholders in Luxembourg", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 89-98, doi: 10.1016/j.cosust.2015.08.006.

Krütli, P., Pohl, C. and Stauffacher, M. (2018), "Sustainability learning labs in small island developing states: a case study of the Seychelles", *GAIA – Ecological Perspectives for Science and Society*, Vol. 27 No. 1, pp. 46-51, doi: 10.14512/gaia.27.S1.11.

Lake, D., Fernando, H. and Eardley, D. (2016), "The social lab classroom: wrestling with—and learning from—sustainability challenges", *Sustainability: Science, Practice and Policy*, Vol. 12 No. 1, pp. 76-87, doi: 10.1080/15487733.2016.11908155.

Larsson, J. and Holmberg, J. (2018), "Learning while creating value for sustainability transitions: the case of challenge lab at Chalmers university of technology", *Journal of Cleaner Production*, Vol. 172, pp. 4411-4420, doi: 10.1016/j.jclepro.2017.03.072.

Leal Filho, W., Ozuyar, P.G., Dinis, M.A.P., Azul, A.M., Alvarez, M.G., da Silva Neiva, S., Salvia, A.L., Borsari, B., Danila, A. and Vasconcelos, C.R. (2022), "Living labs in the context of the UN sustainable development goals: state of the art", *Sustainability Science*, Vol. 18 No. 3, pp. 1-17, doi: 10.1007/s11625-022-01240-w.

Leminen, S. and Westerlund, M. (2019), "Living labs: from scattered initiatives to a global movement", *Creativity and Innovation Management*, Vol. 28 No. 2, pp. 250-264, doi: 10.1111/caim.12310.

Lindstrom, T. and Middlecamp, C. (2017), "Campus as a living laboratory for sustainability: the chemistry connection", *Journal of Chemical Education*, Vol. 94 No. 8, pp. 1036-1042, doi: 10.1021/acs.jchemed.6b00624.

Lotz-Sisitka, H., Wals, A.E.J., Kronlid, D. and McGarry, D. (2015), "Transformative, transgressive social learning: rethinking higher education pedagogy in times of systemic global dysfunction", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 73-80, doi: 10.1016/j.cosust.2015.07.01.

Lozano, R., Merrill, M.Y., Sammalisto, K., Ceulemans, K. and Lozano, F.J. (2017), "Connecting competences and pedagogical approaches for sustainable development in higher education: a literature review and framework proposal", *Sustainability*, Vol. 9 No. 10, p. 1889, doi: 10.3390/su9101889.

McCormick, K. and Kiss, B. (2015), "Learning through renovations for urban sustainability: the case of the Malmö innovation platform", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 44-50, doi: 10.1016/j.cosust.2015.06.011.

McCrory, G., Holmén, J., Schäpke, N. and Holmberg, J. (2022), "Sustainability-oriented labs in transitions: an empirically grounded typology", *Environmental Innovation and Societal Transitions*, Vol. 43, pp. 99-117, doi: 10.1016/j.eist.2022.03.004.

Masseck, T. (2013),"Teaching sustainability through living labs in architecture: the case study of the UPC-LOW3 prototype", *EESD 2013 – Engineering Education for Sustainable Development – Conference Proceedings*, pp. 1-9.

Masseck, T. (2017), "Living labs in architecture as innovation arenas within higher education institutions", *Energy Procedia*, Vol. 115, pp. 383-389, doi: 10.1016/j.egypro.2017.05.035.

Moosavi, S. and Bush, J. (2021), "Embedding sustainability in interdisciplinary pedagogy for planning and design studios", *Journal of Planning Education and Research*, Vol. 44 No. 2, doi: 10.1177/0739456X211003639.

O'Brien, W., Doré, N., Campbell-Templeman, K., Lowcay, D. and Derakhti, M. (2021), "Living labs as an opportunity for experiential learning in building engineering education", *Advanced Engineering Informatics*, Vol. 50, p. 101440, doi: 10.1016/j.aei.2021.101440.

O'Brien, K., Reams, J., Caspari, A., Dugmore, A., Faghihimani, M., Fazey, I., Hackmann, H., Manuel-Navarrete, D., Marks, J., Miller, R., Raivio, K., Romero-Lankao, P., Virji, H., Vogel, C. and Winiwarter, V. (2013), "You say you want a revolution? Transforming education and capacity building in response to global change", *Environmental Science and Policy*, Vol. 28 No. 1, pp. 48-59, doi: 10.1016/j.envsci.2012.11.011.

Onwuegbuzie, A.J., Leech, N.L. and Collins, K.M. (2012), "Qualitative analysis techniques for the review of the literature", *The Qualitative Report*, Vol. 17 No. 28, pp. 1-28, doi: 10.46743/2160-3715/2012.1754.

Pawson, R., Greenhalgh, T., Harvey, G. and Walshe, K. (2005), "Realist review-a new method of systematic review designed for complex policy interventions", *Journal of Health Services Research and Policy*, Vol. 10 No. 1_suppl, pp. 21-34, doi: 10.1258/1355819054308530.

Peterson, R.B. (2018), "Taking it to the city: urban-placed pedagogies in Detroit and Roxbury", *Journal of Environmental Studies and Sciences*, Vol. 8 No. 3, pp. 326-342, doi: 10.1007/s13412-017-0455-4.

Pohl, C., Krütli, P. and Stauffacher, M. (2017), "Ten reflective steps for rendering research societally relevant", *GAIA - Ecological Perspectives for Science and Society*, Vol. 26 No. 1, pp. 43-51, doi: 10.14512/gaia.26.1.10.

Purcell, W.M., Henriksen, H. and Spengler, J.D. (2019), "Universities as the engine of transformational sustainability toward delivering the sustainable development goals", *International Journal of Sustainability in Higher Education*, Vol. 20 No. 8, pp. 1343-1357, doi: 10.1108/IJSHE-02-2019-0103.

Ramchunder, S.J. and Ziegler, A.D. (2021), "Promoting sustainability education through hands-on approaches: a tree carbon sequestration exercise in a Singapore green space", *Sustainability Science*, Vol. 16 No. 3, pp. 1045-1059, doi: 10.1007/s11625-020-00897-5.

Rey-Garcia, M. and Mato-Santiso, V. (2020), "Enhancing the effects of university education for sustainable development on social sustainability: the role of social capital and real-world learning", *International Journal of Sustainability in Higher Education*, Vol. 21 No. 7, pp. 1451-1476, doi: 10.1108/IJSHE-02-2020-0063.

Rivera, C.J. and Savage, C. (2020), "Campuses as living labs for sustainability problem-solving: trends, triumphs, and traps", *Journal of Environmental Studies and Sciences*, Vol. 10 No. 3, pp. 334-340, doi: 10.1007/s13412-020-00620-x.

Rockström, J., Gupta, J., Lenton, T.M., Qin, D., Lade, S.J., Abrams, J.F., Jacobson, L., Rocha, J.C., Zimm, C., Bai, X., Bala, G., Bringezu, S., Broadgate, W., Bunn, S.E., DeClerck, F., Ebi, K.L., Gong, P., Gordon, C., Kanie, N., Liverman, D.M., Verburg, P.H., van Vuuren, D.P. and Winkelmann, R. (2021), "Identifying a safe and just corridor for people and the planet", *Earth's Future*, Vol. 9 No. 4, doi: 10.1029/2020EF001866.

Roswag-Klinge, E., Pawlicki, N. and Crabbe, M. (2019), "Architectural education for a post-fossil future", IOP Conference Series: Earth and Environmental Science, IOP Publishing, *Graz, Austria*, doi: 10.1088/1755-1315/323/1/012157.

Roysen, R. and Cruz, T.C. (2020), "Educating for transitions: ecovillages as transdisciplinary sustainability 'classrooms'", *International Journal of Sustainability in Higher Education*, Vol. 21 No. 5, pp. 977-992, doi: 10.1108/IJSHE-01-2020-0009.

Schäpke, N., Stelzer, F., Caniglia, G., Bergmann, M., Wanner, M., Singer-Brodowski, M., Loorbach, D., Olsson, P., Baedeker, C. and Lang, D.J. (2018), "Jointly experimenting for transformation? Shaping real-world laboratories by comparing them", *GAIA - Ecological Perspectives for Science and Society*, Vol. 27 No. 1, pp. 85-96, doi: 10.14512/gaia.27.S1.16.

Schneider, F., Kläy, A., Zimmermann, A.B., Buser, T., Ingalls, M. and Messerli, P. (2019), "How can science support the 2030 agenda for sustainable development? Four tasks to tackle the normative dimension of sustainability", *Sustainability Science*, Vol. 14 No. 6, pp. 1593-1604, doi: 10.1007/s11625-019-00675-y.

Sharp, E.L., Fagan, J., Kah, M., McEntee, M. and Salmond, J. (2021), "Hopeful approaches to teaching and learning environmental 'wicked problems'", *Journal of Geography in Higher Education*, Vol. 45 No. 4, pp. 621-639, doi: 10.1080/03098265.2021.1900081.

Sterling, S. (2021), "Concern, conception, and consequence: re-thinking the paradigm of higher education in dangerous times", *Frontiers in Sustainability*, Vol. 2, p. 743806, doi: 10.3389/frsus.2021.743806.

Tassone, V.C., den Brok, P., Tho, C.W. and Wals, A.E. (2022), "Cultivating students' sustainability-oriented learning at the interface of science and society: a configuration of interrelated enablers", *International Journal of Sustainability in Higher Education*, Vol. 23 No. 8, pp. 255-271, doi: 10.1108/IJSHE-01-2022-0014.

Tassone, V.C., Runhaar, P., den Brok, P. and Biemans, H.J. (2023), "The added value of exploring course innovations university-wide: an application of a multifaceted analytical course innovation framework", *Higher Education Research and Development*, Vol. 43 No. 2, pp. 1-18, doi: 10.1080/07294360.2023.2253171.

Thornberg, R. and Charmaz, K. (2014), "Grounded theory and theoretical coding", in Flick, U. (Ed.), *The SAGE Handbook of Qualitative Data Analysis*, Sage Publications, London, pp. 153-169, doi: 10.4135/9781446282243.

Thorpe, A. and Rhodes, S. (2018), "The public collaboration lab—infrastructuring redundancy with communities-in-place", *She Ji: The Journal of Design, Economics, and Innovation*, Vol. 4 No. 1, pp. 60-74, doi: 10.1016/j.sheji.2018.02.008.

Trencher, G., Terada, T. and Yarime, M. (2015), "Student participation in the co-creation of knowledge and social experiments for advancing sustainability: experiences from the university of Tokyo", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 56-63, doi: 10.1016/j.cosust.2015.08.001.

van den Heuvel, R., Braun, S., de Bruin, M. and Daniëls, R. (2021), "A closer look at living labs and higher education using a scoping review", *Technology Innovation Management Review*, Vol. 11 No. 9/10, pp. 30-40, doi: 10.22215/timreview/1463.

Veltman, M., Van Keulen, J. and Voogt, J. (2019), "Design principles for addressing wicked problems through boundary crossing in higher professional education", *Journal of Education and Work*, Vol. 32 No. 2, pp. 135-155, doi: 10.1080/13639080.2019.1610165.

Versteijlen, M. and Wals, A.E. (2023), "Developing design principles for sustainability-oriented blended learning in higher education", *Sustainability*, Vol. 15 No. 10, p. 8150, doi: 10.3390/su15108150.

Vilsmaier, U. and Lang, D.J. (2015), "Making a difference by marking the difference: constituting in-between spaces for sustainability learning", *Current Opinion in Environmental Sustainability*, Vol. 16, pp. 51-55, doi: 10.1016/j.cosust.2015.07.019.

Wals, A.E.J. (2019), "Sustainability-oriented ecologies of learning: a response to systemic global dysfunction", in Barnett, R. and Jackson, N. (Eds), *Ecologies for Learning and Practice*, Routledge, London, pp. 61-78.

Wamsler, C., Osberg, G., Osika, W., Herndersson, H. and Mundaca, L. (2021), "Linking internal and external transformation for sustainability and climate action: towards a new research and policy agenda", *Global Environmental Change*, Vol. 71, p. 102373, doi: 10.1016/j.gloenvcha.2021.102373.

Wong, G., Greenhalgh, T., Westhorp, G., Buckingham, J. and Pawson, R. (2013), "RAMESES publication standards: realist syntheses", *BMC Medicine*, Vol. 11 No. 1, pp. 2-14, doi: 10.1186/1741-7015-11-21.

Wortmann, K. (2020), "Drawing distinctions: what is post-critical pedagogy", *On Education. Journal for Research and Debate*, Vol. 3 No. 9, doi: 10.17899/on_ed.2020.9.1.

Zajonc, A. (2013), "Contemplative pedagogy: a quiet revolution in higher education", *New Directions for Teaching and Learning*, Vol. 2013 No. 134, pp. 83-94, doi: 10.1002/tl.20057.

Zen, I.S. (2017), "Exploring the living learning laboratory: an approach to strengthen campus sustainability initiatives by using sustainability science approach", *International Journal of Sustainability in Higher Education*, Vol. 18 No. 6, pp. 939-955, doi: 10.1108/IJSHE-09-2015-0154.

Corresponding author
Marlies L.E. van der Wee can be contacted at: m.l.e.bedeker@hr.nl