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Cross-case knowledge transfer in transformative research: enabling learning in and across sustainability-oriented labs through case reporting

Philip Bernert^{1*†} , Darin Wahl^{2†}, Henrik von Wehrden^{3,4} and Daniel J. Lang^{1,5}

[†]Philip Bernert and Darin Wahl are co-first authors.

*Correspondence: philip.bernert@leuphana.de

¹ Institute for Sustainable Development and Learning, Leuphana University Lüneburg, Lüneburg, Germany

² Lund University Centre for Sustainability Studies, Lund University, Lund, Sweden

³ Center of Methods, Leuphana University Lüneburg, Lüneburg, Germany

⁴ School of Sustainability, Leuphana University Lüneburg, Lüneburg, Germany

⁵ Institute for Technology Assessment and Systems Analysis, Karlsruhe Institute of Technology, Karlsruhe, Germany

Abstract

The field of transdisciplinary sustainability research has brought forward a number of approaches aimed at fostering sustainability transformations and generating knowledge through collaborative experimentation in real-world settings. These cases are strongly embedded in their local context and thus the transfer of knowledge remains a key challenge. In this paper, we propose a case reporting approach that supports the structured and coherent reporting of such cases. This scheme is aimed at sustainability-oriented labs, where sustainability solutions are collaboratively developed through experimentation. The scheme focuses the reporting on local contexts, lab processes, and experiments. It is accompanied by a logic model and a set of four principles guiding the reporting procedure. The approach is designed to be general, in that it is applicable to diverse contexts and project designs, while its modularity allows the scheme to be adapted to the needs and specifics of each cases. The scheme was jointly developed and tested by a group of seven Urban Living Labs, each in their own unique context. With our approach we aim to contribute to knowledge transfer from and across cases of sustainability-oriented labs as emerging approaches in action-oriented research bridging the divide of case-based research and (meta) comparison.

Science highlights

- Urban Living Labs and similar sustainability-oriented labs are promising settings for exploring sustainability transformations.
- Knowledge transfer across such cases is challenged by the high degrees of context specificity.
- We present a reporting scheme that allows for a structured reporting of contexts, labs, and experiments.
- Case reporting enables knowledge transfer and cross-case learning in transdisciplinary and transformative sustainability research.



Policy and practice recommendations

- ULLs and real-world labs are research settings for exploring sustainability transformations through joint experimentation.
- The proposed case reports can be a knowledge base for research and practice.
- To enable transferability and comparison of the conducted research, case reports should cover descriptions of context, lab, and experiments.

Keywords: Urban living labs, Real-world labs, Experimentation, Evaluation, Transdisciplinarity, Reporting, Knowledge transfer

Introduction

Urban Living Labs (ULL) and other types of “sustainability-oriented labs in real-world contexts” (McCrorry et al. 2020) are research settings for investigating and engaging with sustainability challenges in local contexts. These action-oriented research settings aim to contribute to sustainability transformations by establishing and enabling transdisciplinary collaborations between scientific actors and actors from other societal domains to develop sustainability solution options through joint experimentation (Nevens et al. 2013; Voytenko et al. 2016; Schöpke et al. 2018; McCrorry et al. 2020). Several lab approaches have been proposed and coexist, e.g. real-world laboratories, urban living labs, transition labs, and transformation labs. These ‘sustainability-oriented labs in real-world contexts’ have developmental roots in socio-technical transitions (Nevens et al. 2013; Schöpke et al. 2018; Sengers et al. 2019; McCrorry et al. 2020) and Schöpke et al. (2018) find that they share key dimensions including a transformative focus, experimental methods, learning and reflexivity, a long-term orientation, scalability, and transdisciplinarity.

However, there is a lack of insight into the role played by ULLs in substantiating knowledge to solve sustainability challenges beyond the local level (von Wirth et al. 2019; Laborgne et al. 2021). ULLs conduct sustainability experiments where innovative ‘solutions’ to sustainability problems can be tested and refined (Bulkeley et al. 2016, 2019). Approaching the often-complex societal processes through experiments provides evidence on sustainability problems and their potential solutions, through which learning and actionable knowledge are co-produced (Caniglia et al. 2017). Experiments in these settings can vary widely, from developing novel technologies to new arrangements, strategies, ways of doing or relating, business models or policy approaches (Frantzeskaki et al. 2018; Sengers et al. 2019; von Wirth et al. 2019; McCrorry et al. 2020). In this regard, we agree with Hodson et al. (2017) that a “looser view of the experimental process” is helpful. However, approaching the often complex societal processes through experiments provides evidence on sustainability problems and their potential solutions, through which learning and actionable knowledge are co-produced (Caniglia et al. 2017).

Transdisciplinary research in ULLs, therefore, aims to develop knowledge that is largely case-specific and place-embedded (Frantzeskaki et al. 2018) in contrast to more classical research that tends to produce generalisable results (Adler et al. 2018). This difference can be seen as a critical challenge in terms of the knowledge generated in ULLs, the transfer of knowledge across ULLs and the learning from case studies in ULLs. The strong contextual embeddedness of every case in these settings

Table 1 The GLOCULL project

The GLOCULL project aimed to advance ULL research by grouping several ULLs under the shared theme of the FWE nexus as part of the JPI Urban Europe funding scheme SUGI (Sustainable Urbanisation Global Initiative). The ULLs in GLOCULL cover a broad range of geographical contexts, actor configurations and purposes (see Table 2). They were all deeply rooted in their local contexts, building on pre-existing relationships with local partners. The form of the ULLs differed in many ways, including their local contexts, governance structures and size. The experiments and interventions developed and realised in the GLOCULL labs adopted a broad variety of methodological approaches and addressed diverse sustainability challenges.

Through its design, the project aimed to generate new insights into 1) the development of local FWE innovations; 2) interdisciplinary international collaboration through the consortium; and – central to this paper – 3) the comparability, better generalisability and transferability of lab and experiment learning and outcomes.

leads to a high degree of individuality and a strong interdependency between the local context and the validity of the results. Although the discourse on this challenge is not new (e.g., Krohn 2017), approaches concerning the transferability of knowledge between transdisciplinary case studies are still rare (Adler et al. 2018) – and ULLs are no exception in this regard.

Against this background, we propose case reporting as a promising approach for capturing the knowledge contained and produced in ULLs. Our suggested use of case reporting is inspired by its long-established practice in the fields of medicine and public health (Marone 2012), where it is an essential practice that reliably makes single cases available to the scientific community to learn from and to generate further insights using established methodological approaches. Case reporting is key in facilitating the sharing of observations and learning from practice settings (Vandenbroucke 2001) and has proven crucial to initiate both experimentation and comparisons across cases (Albrecht et al. 2005). Case reports in the fields of medicine and public health follow a coherent structure that is designed to be searchable and familiar to other reporters and researchers. In other words, the guiding principle behind case reporting is not only to report what was accomplished, but also to explain how and why experiments were conducted to reach those outcomes and outputs.

To illustrate how a case reporting approach could be applied in ULL research and beyond, we present a comprehensive case reporting scheme (case reporting scheme) and guidelines developed in an international project consortium. This reporting approach guides researchers on how to structure reports on real-world cases to cover the crucial aspects of these cases while ensuring the coherence and comparability of the reports. The proposed scheme's development was guided by the questions: *How do we capture the diverse context specificities and design of ULLs so that the insights are relevant for both academics and actors from other societal domains in the ULL and beyond?* The presented approach was originally developed as part of the GLOCULL research project (see Tables 1 and 2), a consortium of seven ULLs engaged in developing sustainable innovations around the food, water and energy (FWE) nexus. Our approach builds on concepts around the evaluation of transition experiments (e.g., Luederitz et al. 2017) but expands the focus of reflection to the processes of the lab and its context in order to target knowledge sharing and comparison.

The case reporting scheme and approach we present are a contribution to the growing discourse around action-oriented sustainability research. We consider case

Table 2 GLOCULL labs - the ULLs, briefly described below, are diverse in terms of their context, lab design, sustainability orientation and experiments

Lüneberg, Germany - as part of the Zukunftsstadt Lüneberg 2030+ programme, the lab explored fair and sustainable supply chains and consumer interaction with independent coffee houses.
Lund, Sweden - the SustBeerLab explores the development of sustainability strategies and innovations with craft brewers in the Skåne region.
Maastricht, Netherlands - the SuperLocal Lab tests sustainable technologies and construction in a housing development community.
Phoenix, USA - the academic team partners with municipalities to run an innovation accelerator that supports small businesses in implementing sustainable practices.
São Paulo, Brazil - researchers work with municipality practitioners to co-develop a set of indicators to assess the sustainability of local agriculture initiatives.
Stellenbosch, South Africa - researchers partner with a township gardening/urban farming initiative promoting food sovereignty and fresh healthy food options.
Vienna, Austria - researchers and farmers test the impact and feasibility of using photovoltaic panels on greenhouse farms.

reporting a way forward to bridge the divide of case-based research and (meta) comparison in sustainability science.

A collaboratively developed case reporting approach for Urban Living Labs

The development of the case reporting scheme (case reporting scheme) as presented below was an iterative process comprising several phases. From the initial ideas phase and background research to testing and refinement took more than 18 months. The people involved centred on a core group of two (the lead authors of this paper) who collaborated with a working group of 12 researchers (mostly early-career) and then with the entire GLOCULL project (30+ researchers) as well as country-based teams. Many steps were iterative, requiring the core team to reach out for various feedback from the larger groups. The following section outlines the phases in more detail.

The project goals (particularly goal 3) required the development of an evaluation strategy that would allow for comparisons to be made between ULLs and their experiments. The team agreed on criteria to guide the scheme development: the scheme should be 1) *comprehensive* i.e. it should capture the scope of the potential activities, processes, impacts and influences of the labs; 2) *broad* i.e. it should be general enough to capture the range of purposes and contexts represented by the GLOCULL ULLs; and 3) *built on established frameworks* i.e. it should reflect the contributions of previous relevant and applicable research.

The idea for case reporting came from the recognition that existing evaluative frameworks were unable to capture the processes that influence the progress made in our labs in a way that makes comparison possible (Palmer et al. 2020). Recent evaluation schemes of real-world and transition experiments have been developed and applied (Luederitz et al. 2017; Luederitz et al. 2017; Williams and Robinson 2020; Kampfmann et al. 2022), although such evaluations predominantly focus on the experiments and, therefore, target innovations and their development. Furthermore, evaluation as it is often practised is predominantly inward facing, in that its target audience is the team members, funders, lab and experiment designers, and other invested parties (Williams and Robinson 2020). In addition to that function, our goal was to effectively compare these case studies in order to derive actionable knowledge relevant beyond the specific local contexts. In

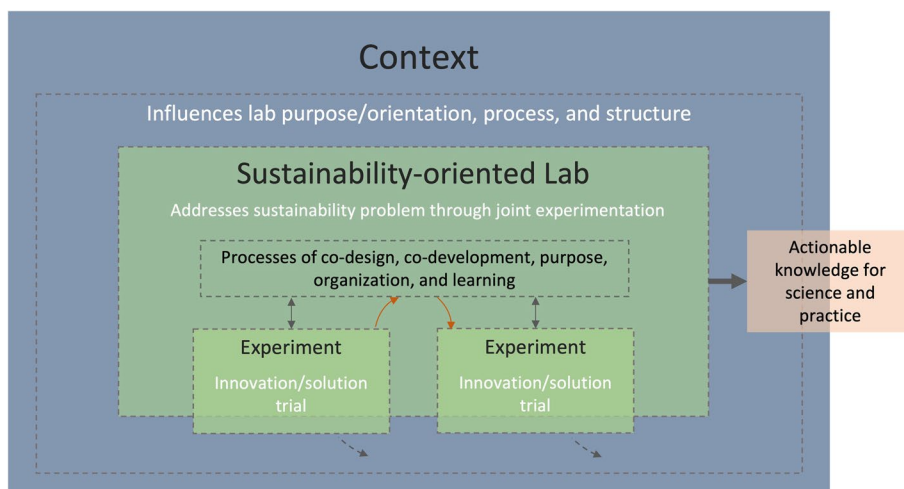


Fig. 1 The logic model shows the semi-nested nature of the context, lab and experiments, and the purposes/functions of each domain

other words, each case is communicating to people who are unfamiliar with the details of the specific case, but the intention is that the details of one case can be a space of inspiration, learning and comparison for another. In this sense, similar to Williams and Robinson (2020), the scheme we developed required a strong focus on the processes of conducting a lab and running experiments but is equally intended for an external audience.

Conceptualisation

In order to conceptualise the case reporting scheme, it was necessary to identify those elements and activities in the labs that could be compared, as well as to determine how to simultaneously include and exclude the anchoring effect of the local context. A logic model was developed to differentiate between the context of the lab, the lab elements and processes, and the experiments (see Fig. 1). This differentiation unlocked the potential for researchers to use the case reporting scheme to target specific aspects for comparison; for example, the use and impact of particular tools and methods. The characteristics related to the context could then be categorised or could be disregarded as being of no influence.

The logic model is an approach for conceptualising ULLs and related sustainability-oriented lab approaches and for structuring their reporting. The literature on the various lab approaches makes no clear distinction between the actual experiments, the supporting lab structure, and the overall local context in which both are embedded. The disambiguation of context, lab and experiment shared by Kampfmann et al. (2022) offers the potential for a clearer understanding of the purposes of each aspect and how they influence each other. The logic model follows an ideal–typical understanding of context, lab and experiment, as well as their interactions (cf. Jahn 2008; Wanner et al. 2018).

The *context* is defined by the local social, political, geographical, and economic conditions in which the Lab is situated, and which are relevant to Lab participants and activities. These conditions are crucial for understanding the work that is to be accomplished

in the ULL. Our context understanding follows the theoretical considerations by West et al. (2019) in that the *relevant* context is what the practice – the lab process and experiments – is entangled with and has to navigate (Van Steenberghe and Frantzeskaki 2018). Similar to their understanding, we view the context as the external conditions that are relevant from the case's perspective but equally need to be uncoupled from this perspective to allow for comparison between cases.

The *lab* is a 'space'¹ collaboratively created by scientists and actors from other societal domains to co-produce sustainability pathways or solutions. Within the *lab*, the processes governing its design, development, purpose and organisation are continuously negotiated and established (Wanner et al. 2018; Bulkeley et al. 2019; McCrory et al. 2020), which results in relevance, credibility and legitimacy of the work undertaken for both science and practice (Cash et al. 2003). The structure and framing of the lab create the space in which sustainability experiments are developed and carried out.

The *experiments* are deliberately designed and evaluated interventions in local real-world contexts and are the core research method of transdisciplinary and transformative lab approaches. They are collaboratively conducted and partially controlled within the *lab* space. The *experiments* produce evidence and create knowledge and other outputs that are then evaluated, integrated and in other ways processed in the lab and beyond (Castán Broto and Bulkeley 2013; Caniglia et al. 2017; Sengers et al. 2019). If the lab continues, they are used to develop successive experiments and potentially to create innovations that are scalable and/or transferable (Neuens et al. 2013; Schöpke et al. 2018). Otherwise, the new knowledge generated is integrated back into society and science through the participating actors, publications, networks and other means of communication and outreach as determined by the lab (Lang et al. 2012).

Prototyping and first application/reflection

The case reporting scheme was outlined over the course of two face-to-face project meetings in Stellenbosch, South Africa, and Tempe, USA. The methodological guidelines for a coherent evaluation process were developed during the follow-up project meeting at Leuphana University in Lüneburg, Germany. Between these meetings, as well as afterwards, GLOCULL researchers met online monthly to further develop the scheme. For the Tempe meeting in the USA, project teams developed case-specific questions based on elements they had determined as key, unusual or otherwise relevant and then categorised them according to the logic model. In the monthly meetings, the case-specific questions were integrated with evaluative questions found in the existing sustainability-oriented lab/experiment literature and then categorised and synthesised to become the scheme's guiding questions (see Tables 3, 4 and 5).

To establish context characteristics, we drew largely on Forrest et al. (2019) (see Table 6), which provided the necessary framing to describe the general relevant local context characteristics for the lab and the experiments. These categories are sufficiently broad yet provide appropriate distinctions for reporters to identify relevant case-specific

¹ This space can be both literal and metaphorical in that it could be helpful to have a physical space where participants meet and carry out activities, but more important is the metaphorical space created when parties agree and commit to participate/collaborate in the lab process.

Table 3 The context section of the case reporting scheme outlining constructs and their associated guiding questions

Context	What are the general factors that describe the context in which the lab and its activities are located and entangled? How do they influence the lab and its activities?
Construct	Guiding Question
Environmental	What are the relevant environmental factors (biological or physical), such as climate, soil type or vegetation?
Social/Cultural	What are the relevant socio-cultural factors, such as history, diversity, education, income, health, language, religion, values, beliefs and social norms?
Financial/Economic	What are the relevant socio-economic factors, such as taxes, diversity of enterprises, unemployment and diversity of workforce?
Technical/Infrastructure	What are the relevant technical or infrastructure factors, such as water and energy infrastructure, transport networks, housing stock, green infrastructure or other built environment?
Legal/Political	What are the relevant legal or political context factors, such as laws, regulations, standards, permits, dominant ideology, activism and public participation?
Organisational/Capacity	What organisational or capacity factors (such as knowledge, skills, organisational structures, networks, training programmes and support services) have a significant influence on the lab's purpose or activities?

elements and key details. To establish the lab characteristics, we began with a set of key characteristics of sustainability-oriented labs proposed by Schöpke et al. (2018). We then drew on a variety of ULL, Real-world lab, T-Lab, and Transition lab literature, including review papers (McCrory et al. 2020; e.g., Bergmann et al. 2021), along with literature on transdisciplinary sustainability research design principles (Lang et al. 2012). To establish the characteristics of the experiments and as inspiration for many of the guiding questions in the case reporting scheme, we drew on the comprehensive work of Luederitz et al. (2017), which reviewed the experiment literature to develop an evaluative scheme for sustainability experiments.

The case reporting scheme

The case reporting scheme consists of three main components following the logic model – the context, lab, and experiment – along with a short set of instructions for the reporting process. The scheme structures the processes, insights, results and experiences from sustainability-oriented lab research and its experiments in an accessible way. The structure of the scheme reflects the components of the logic model and their interconnections as described above. Each of the case reporting scheme's features is addressed through a guiding question. The case reporting scheme is presented in the tables below, followed by examples from the GLOCULL project showing how questions can be answered.²

Context features

These characteristics aim to represent relevant context aspects framing the lab and its experiments. The context can also be useful in capturing the system limits that cases set

² The scheme as presented in the following sections of this paper is an updated version of the scheme originally used in the GLOCULL project. While the general structure and most of the questions are identical, some changes were made to enhance the scheme's generalisability during the conceptualisation and writing of this paper. We are confident that the quality of the scheme has improved and is now up to date with regards to the literature it integrates.

Table 4 The lab section of the case reporting scheme outlining constructs and their associated guiding questions

Lab	What is the general purpose, structure and composition of the lab? How were these determined/negotiated/carried out?
Construct	Guiding Question
Space	
Spatial scope	What is the spatial scope of the lab's activities, such as relevant geographical and/or administrative boundaries?
Temporal scope	What is the temporal scope of the lab's activities? What previous work is crucial to understanding the lab's current work? What is the lab's future and long-term perspective?
Process	
Experimentation	What is the general experimental methodology adopted by the lab (e.g., testing innovations/exploring sustainability solutions)? How is the control of experiments managed/distributed? Are experiments problem or solution oriented? What are the main experiments undertaken in the lab? How were these determined?
Collaborative process	What is the general process of collaboration in setting up the lab and the accompanying experiments? How did participants collaborate (e.g., share responsibilities, organise decision-making processes, etc.)? Which groups/voices are lacking or under-represented? Why?
Learning and reflexivity	How does the lab enable learning and create spaces for reflexivity (including knowledge synthesis and integration)?
Activities	What further activities support the lab process?
Organisation	
Organisational structure	What is the general organisational structure of the lab (including the funding scheme, financing, etc.)? Who are the primary participants in the lab and experiment(s)? Indicate their representative roles (e.g., academic, private, municipal) within the process. What roles were determined for running and maintaining the lab and experiments? Did central roles change over the course of the lab? How does the lab deal with conflict situations?
Sustainability	
Sustainability orientation and purpose	What sustainability problem is addressed by the lab? What sustainability understanding is adopted to address the problem/s? How was this understanding reached? Did the understanding deepen over the course of the lab? For whom?

for themselves. We understand context as the external and environmental factors that the lab and experiments are entangled with (Van Steenberg and Frantzeskaki 2018).

In the GLOCULL project, the context section provided an opportunity for labs to reflect on local spaces and how they interact with the lab and its activities. For instance, the SUSTBEERLAB in Lund, Sweden, identified the socio/cultural context factors as follows:

There is an underlying class, gender and race (middle-class, male, white) broadly associated with the craft brewing industry (both in terms of those who work in the industry and its target audience). There are some exceptions to these norms as craft brewing is a growing sector in different cultures (e.g., Japan). The industry is also dependent on those with leisure time and disposable income. These aspects form the basis of the "social" components of lab activities. Cracks, however, are emerging, especially in terms of the race and gender components (e.g., gender ambassadors, female brewing groups/female-operated breweries).

Table 5 The experiments section of the case reporting scheme outlining constructs and their associated guiding questions

Experiment Construct	How were the experiments conducted; what did they generate? Guiding question
Outputs	What kind of outputs were generated through the experiment?
Built capacities	What capacities were created through the experiment?
Actionable knowledge	What actionable knowledge was generated through the experiment? How did it provide evidence on generating sustainability solutions?
Accountability	How did the experiment build confidence and commitment for generating and realising sustainability solutions?
Changes in physical structures	What physical changes were made to support solutions for the identified sustainability problem?
Changes in social structures	What changes in social structures were made to support solutions for the identified sustainability problem?
Transferability	How does the experiment ensure that the sustainability solution can be transferred to different contexts?
Scalability	How does the experiment indicate the method and potential for outputs to be scaled to broader applications or to higher hierarchical levels?
Unintended consequences	How does the experiment account for unintended consequences that are associated with the sustainability-oriented intervention?
Outcomes	How did the experiment contribute to sustainability?
Socio-ecological integrity	How did the experiment's outputs strengthen socio-ecological integrity?
Livelihood sufficiency and opportunity	How did the experiment's outputs enhance livelihood sufficiency and opportunity?
Intra- and intergenerational equity	How did the experiment's outputs improve intra- and intergenerational equity?
Resource maintenance and efficiency	How did the experiment's outputs contribute to overall resource maintenance and efficiency?
Socio-ecological stewardship and democratic governance	How did the experiment's outputs build or support socio-ecological understanding and democratic governance?
Precaution and adaptation	How did the experiment's outputs ensure precaution and adaptation?
Processes	How was the experiment designed and conducted?
Sequence of actions	Was the experiment structured in a meaningful sequence of actions?
Sound methodology	What was the methodology used to conduct the experiment?
Collaboration	How did the experiment facilitate collaboration among relevant stakeholders?
Reflexivity and learning	How did the experiment foster reflexivity and learning throughout the process?
Transparency	How did the experiment ensure transparency throughout the process?
Inputs	What were the enabling factors of the experiment?
Awareness	What was the level of awareness of the need for transformational change? How did the experiment involve participants aware of the need for transformational change?
Commitment	What commitment did the experiment build on?
Expertise	What skills and knowledge did the experiment build on?
Trust	What trust among collaborators did the experiment build on?
Support	What support was secured for the realisation of the experiment?

Table 6 The general framing and topic areas/characteristics of the context, lab and experiment for the case reporting scheme and the corresponding literature

Context Features	References
Environmental, social/cultural, financial/economic, technical/infrastructure, legal/political, organisational/capacity	Forrest et al. 2019; Van Steenberghe and Frantzeskaki 2018; West et al. 2019
Lab Features	References
<i>Space</i>	McCrorry et al. 2020
Geographical embeddedness, real-world problem as a starting point, boundaries: lab demarcations – content, space, location and scope	Voytenko et al. 2016; Wanner et al. 2018; Bulkeley et al. 2019
Background and history, long-term orientation	Forrest et al. 2019; Schöpke et al. 2018; Bulkeley et al. 2019
<i>Process</i>	McCrorry et al. 2020
Experiments as core research method, experimentation and learning, real-world intervention	Voytenko et al. 2016; Wanner et al. 2018; Schöpke et al. 2018; Caniglia et al. 2017
Transdisciplinarity as core research mode; systems, target and transformation knowledge; participation and user involvement; participants, power, legitimacy, credibility, salience, inclusion	Voytenko et al. 2016; Wanner et al. 2018; Adler et al. 2018; Schöpke et al. 2018; Sengers et al. 2019; Lam et al. 2020a, b; Caniglia et al. 2017; Cash et al. 2003; Bergmann et al. 2021; Avelino 2017; De Geus et al. 2022
Learning and reflexivity, cyclical learning: reflection and variation, evaluation (of actions and impacts) and refinement of knowledge; capacity building	Voytenko et al. 2016; Wanner et al. 2018; Schöpke et al. 2018; Singer-Brodowski et al. 2018; Ness and Wahl 2022; Lang et al. 2012; Wiek et al. 2017; Bergmann et al. 2021
Participatory methods, tools, exercises, workshops for e.g., skill and capacity development, system thinking and definition	Bulkeley et al. 2019; Lang et al. 2012; Bergmann et al. 2021
<i>Organisation</i>	McCrorry et al. 2020
Leadership and ownership of ULLs, TD collaboration (co-leadership)	Voytenko et al. 2016; Wanner et al. 2018
Collaboration, responsibility, time allocation, organisational process, organisational champion	Wittmayer & Schöpke 2014; Wittmayer et al. 2017; Ness and Wahl 2022
Facilitation, trust, communication	Lang et al. 2012; Ness and Wahl 2022
<i>Sustainability</i>	McCrorry et al. 2020
Contribution to transformation, normative framing, real-world problem, purpose, scalability and transferability of results (amplification), empowerment of change agents	Wanner et al. 2018; Schöpke et al. 2018; Forrest et al. 2019; Lam et al. 2020a, b; Lang et al. 2012; Pereira et al. 2020; Wiek et al. 2017
Experiment Features	Reference
<i>Outputs</i>	Luederitz et al. 2017
Built capacities, actionable knowledge, accountability, changes in physical structures, changes in social structures, transferability, scalability, accounting for unintended consequences associated with uptake	
<i>Outcomes</i>	
Socio-ecological integrity, livelihood sufficiency and opportunity, intra- and intergenerational equity, resource maintenance and efficiency, socio-ecological stewardship and democratic governance, precaution and adaptation	
<i>Processes</i>	
Sequence of actions, sound methodology, collaboration, reflexivity and learning, transparency	
<i>Inputs</i>	
Awareness, commitment, expertise, trust, support	

It also provided a space for reflection on the connections between the context conditions and the practices of the lab's local partners. For instance, the ULL in Vienna, Austria, explained:

The environmental factors are to some extent controlled inside the greenhouse. Coconut fiber is used instead of soil. The type of vegetables grown inside the greenhouse determines the necessary inside temperature, sunshine or shading and watering. According to the gardeners, the levels of sunshine are more important than the outside temperature for regulating the optimum temperature inside the greenhouse for growing vegetables. Climate conditions, including wind, influence to what extent the gardeners need power for ventilation and for irrigation in the greenhouses, which affects the consumption of energy (the energy is produced by PV panels). The economic potential of the ULL generally depends on climatic conditions and their change over time. More precise measurements with respect to environmental conditions were beyond the scope of our experiment.

Laboratory features

We propose to use the four categories identified by McCrory et al. (2020) in their review of real-world lab types to structure this section: space, process, organisation and sustainability. These categories consider where a lab is located, why and when a lab is convened, what and how actions are taken, the roles and influences of and on lab participants, and their intended sustainability purpose.

GLOCULL labs answered the lab section in a variety of ways, with some offering narrative and detailed answers, while others preferred a concise academic approach like the following from the ULL in Lüneberg, Germany, in their response to the experimentation questions:

The central experiment conducted in the lab (the co-development and implementation of a communication strategy for transparency in sustainable coffee businesses) is considered a type 5 experiment, i.e. an experiment on sustainability solutions with participatory control (Caniglia et al. 2017), with an embedded analytical aspect that adopts a methodological approach from business psychology (Weber et al. 2021). The topic/real-world problem was selected as a crucial aspect of the café's transition to becoming a collectively-managed sustainable coffee shop with a local roastery devoted to transparent business practices.

In response to the sustainability questions, the same ULL explained:

The experiment in the lab mainly revolved around the aspect of "transparency". This focused on the coffee supply chain as well as having the general aim of making contributions to increase sustainability in the food-water-energy nexus. Related social questions, such as income and the living/working conditions of producers, were also considered. On a local level, the lab aims to encourage the residents of Lüneburg to adopt more sustainable consumption patterns.

Experiment features

The experiment features build on the comprehensive evaluation scheme presented by Luederitz et al. (2017), which deconstructs experiments into inputs, processes, outcomes and outputs. The four categories correspond to the answers to the following general questions: *What was generated?* (outputs); *what was accomplished?* (outcomes); *how was it completed?* (process); and *what was invested?* (inputs) (Luederitz et al. 2017). While we have adopted this overall framing, we have added or changed the guidance to highlight the related processes using *how* questions along with *what* questions.

Used as a reflexive tool, the case reporting scheme can identify process challenges from multiple perspectives. For example, in response to the *transparency* questions, the Sao Paulo GLOCULL team reported the following:

With the aim of ensuring transparency throughout the process, the decision was made to focus on communication between actors and a formal agreement was drawn up. However, some participants recognised that there were flaws in the communication process in the ULL, since the goals initially agreed by the group were adjusted along the process and not all the participants were notified. This highlights the importance of establishing transparent modes of communication between all the actors. An agreement between the university and the Municipal Secretariat of Urban Development and Licensing was developed and signed. However, due to changes in the public administration and bureaucracy, this agreement was never fully formalised. This impacted on the information sharing from the municipality and, consequently, on the compilation of the sustainability indicators forms. Nevertheless, some participants pointed out that shared responsibilities had been clearly established at the beginning of the process, which was helpful for building trust within the group. (Researchers' perspective, interviews with ULL participants)

Reporting procedure

Our structured case reporting scheme aims to support and simplify reporting practice. Yet, for the reporting to meet its potential to increase learning across cases and improve the comparability of cases, the process needs to be coherent.

Therefore, we have developed a brief list of principles to guide the reporting:

- 1) *Start from the experiment.* Centering the reporting around the experiment provides the necessary focus for a pragmatic and target-oriented reporting process. By putting the experiment at the centre of the report, the cases can be constructed/reconstructed more easily as the description of the lab and context is guided by the question of what was relevant to the experiment.
- 2) *Use available data.* The reporting suggested in this paper does not necessarily require the collection of new data. We have learned in our research practice that much of the required information is already available in the form of meeting minutes, research and reflection journals, schedules, annual and midterm reports, etc. The reporting does not aim to replace empirical methodologies where they are needed, but rather

provides a coherent structure for communicating project characteristics and trans-disciplinary research insights.

- 3) *Disambiguate context, lab, and experiment.* The reporting builds on an intentional disambiguation of context, lab, and experiment. While in reality these three aspects of lab-based action-oriented research are inherently interconnected, they need to be described separately to enhance their understanding from an outside perspective. The deliberate disentangling of cases facilitates the transferability of the case report content, as a first step in conceptualising real-world research.
- 4) *Adapt to case specifics.* We suggest viewing the case reporting scheme as a modular tool. It should reflect the goals and purpose of each case study, meaning that questions central to a particular case can be answered in greater detail where others may be more generally described. It is also important to note that each experiment in a case should have its own reporting space. In many cases, labs conduct more than one experiment. Moreover, if the questions are too broad for the purpose, they can be given more detail using what we call horizontal specification: the original features and questions of the scheme remain as categories but are complemented by additional case-specific questions.

Discussion

The case reporting scheme as a pragmatic tool balancing comprehensiveness and specificity through modularity

The scheme as presented in this paper was designed as a tool for a reporting approach that is integrative and thus applicable in a diversity of contexts, lab designs and experiments. The case reporting scheme balances the need for a structural framework that enables comparisons between cases with the flexibility necessary to adapt to the specifics of cases, designs and context that are inherent in transdisciplinary and transformative research in ULLs. Consequently, the features of the scheme and the questions cover a broad range of lab features, context qualities and aspects of sustainability-oriented experiments. With the aim of generating research reports that are more comprehensive, the case reporting scheme has the potential to better capture emergent results from transdisciplinary labs and experiments in a structured manner.

While the scheme itself is designed as a descriptive tool and built around a clear disambiguation of context, lab process and experiments, it recognises these three aspects as inherently interconnected. By centering the reporting around the experiment and lab process, the intention is to describe the context *relevant* to the research practice, adopting the notion of contexts as constructed by this practice (West et al. 2019). While this might seem complicated at first, in practice a reporting sequence starting from the experiment, describing the lab process around it and then the context factors relevant for the case, allows the reporting process to follow these considerations.

The case reporting scheme is purposefully designed to be fairly general in order to integrate a diversity of cases: it is intended to be adapted to meet the specifics of case study contexts and labs, as well as experiment designs. Through the bottom-up (initial collection of the case-specific questions) and top-down (alignment with existing frameworks) process of developing the case reporting scheme, we were able to ensure that

the scheme is appropriately case-oriented and, therefore, functional for researchers and actors in transdisciplinary research settings.

However, the case reporting scheme is intended to be customised in such a way to enable comparability beyond an individual case/project – and to achieve that, most questions should remain constant. However, specific elements can be highlighted in questions to target case/project specific priorities. Furthermore, questions can be added to the scheme; for example, to allow for a particular type of analysis. It should be noted, however, these amendments and adaptations should be discussed and decided upon at an early stage in the research to align research design, assessment, and evaluation. Beyond the content of the case reporting scheme, questions regarding who should complete the report and who has what data or knowledge are significant – especially if the decision is taken that parts of the report are to be completed as a reflexive activity with non-academic participants.

One of the key aspects of the case reporting scheme lies in its modularity. It enables the reporting to trace the uniqueness of each project through the reported aspects in each section. Consequently, that uniqueness is made explicit in each of the sections and the influence of certain characteristics are seen as they interact with processes and decisions taken in the lab and during the experiments. Furthermore, the modularity creates the potential for the case reporting scheme to be adapted to the specific interests of projects without the need to develop an entirely new reporting structure.

The case reporting scheme as a reflexive tool for collaborative planning and learning

Through its comprehensive design, the case reporting scheme includes a wide range of aspects to consider when designing and planning lab-based sustainability-oriented research settings. The case reporting scheme can be used as a guide for developing context understanding and reflecting on the research design, in terms of *inter alia* priority setting, data collection, purpose setting, methods or activity planning. It is particularly useful for guiding the discussion of these aspects at an early stage, for example, in anticipation of cross-case comparisons and developing methods and tools. The case reporting scheme can be used iteratively to track changing perspectives, project, lab or experiment evolutions, participating-actor turnover or additions, or major changes in local contexts e.g., COVID-19 and associated restrictions.

The case reporting scheme and the theoretical understandings from which it is derived have proven useful for critically inspecting lab designs and addressing aspects that may have been initially overlooked. In some cases, the case reporting scheme has proven especially useful for supporting the development and planning of experiments that were only described in vague terms at the outset of the project. At international consortium level where cooperation between research teams from different labs is essential, the case reporting scheme (and its development process) has played a crucial role in aligning research approaches by establishing a shared methodological understanding as a basis for the individual lab work.

In this context, the case reporting scheme can be used reflexively as a participatory or non-participatory tool to enable mutual learning. The more users engage in the process of thinking about how the questions relate to their case, the more the answers can reveal unexpected learnings. In such instances, the case reporting scheme can support

a structured learning and reflection process that integrates different perspectives in the research. While our case reporting scheme offers a structure for reporting on crucial aspects of contexts, labs, and experiments, integrating a quality assessment not only fosters learning within cases, but also enriches the knowledge conveyed in case reports (Williams and Robinson 2020; Jain and Rohrer 2022).

Knowledge transfer and comparison

Compared to other modes of research, knowledge generated in transdisciplinary and transformative research settings is characterised by a high degree of context-specificity, creating knowledge based on (single) cases that may potentially be applied to other (single) cases. The challenges of knowledge transfer in these contexts was made clear by Adler et al. (2018). They argue that it must be distinguished from the traditional notion of generalising knowledge across cases, and instead the authors suggest the building of analogies.

Our case reporting scheme approach aligns with this notion and can provide a basis for such analogy-based knowledge transfer. We follow the idea that “insights” or “results” from lab-based research processes cannot be implemented “as is” in different contexts, let alone be replicated in its entirety elsewhere (in contrast to traditional experiments). Instead, case reports can be a basis for building analogies. By offering a comprehensive perspective on (single) cases, case reports enable researchers to find similarities and dissimilarities and identify that knowledge which is applicable to their own and other cases. By making context, lab design, and experiments explicit, our case reporting scheme provides the basis for exploring amplification strategies for solutions that have been developed and tested in other contexts (Lam et al. 2020a, b).

By enabling researchers to communicate their case-specific research coherently and comprehensively, case reports can play a role in bridging modes and approaches. Instead of highlighting differences, the case reporting scheme frames cases as complementary to each other: all parts of a gradient ranging from highly case-specific and impactful approaches able to recognise existing local sustainability initiatives (Lam et al. 2020a) to more generalisable and empirically rigorous methodologies, such as harmonised experimentation (Ferraro and Agrawal 2021), randomised controlled trials (Bilotta et al. 2014) or meta-analytical approaches.

Case reports are data. While this data may be less generalisable than the insights generated through more rigorous methodologies and study designs, structured and collaborative case reporting can be representative of the ecological validity (Scholz and Tietje 2002) of transdisciplinary research. Consequently, case reports could be a promising data source in the field of sustainability research for generating hypotheses through comparative approaches appropriate for dealing with complex and often mixed data, e.g. Rough Set Analysis (Pawlak 1997; e.g., Nijkamp et al. 2002; e.g., Lutz et al. 2017) or Qualitative comparative analyses (e.g., Hilger et al. 2018).

Case reports can be written and considered as case narratives. Following the case reporting process and thinking of external readers can shift the way cases are communicated between researchers and add a *thick description* (Geertz 1973) to the otherwise focused and therefore narrower perspectives offered by case studies. A narrative storytelling approach rich with detail and aimed at process understanding puts the

transdisciplinary aspects of the research at the centre, allowing others to learn from the trials and tribulations of cases (e.g., Schwartz-Shea and Yanow 2013). Kenter et al., (2019) suggest Loving the Mess while navigating transdisciplinary collaborations, and while we agree, we think that sharing the mess with others will facilitate future process navigations.

Through a case reporting practice shared across the field of action-oriented research, a rich knowledge-base on sustainability approaches could be built. We recognize that a number of journals already publish article types aimed at sharing process and design knowledge from transdisciplinary research constellations (e.g., Sustainability Science and GAIA) that enable learning from real-world cases. Basing such articles on a shared reporting scheme such as the one presented here, would further establish these articles as a rich knowledge base for enabling sustainability transformations while incentivizing case reporting through peer-reviewed publications. Furthermore, the establishment of dedicated sustainability-oriented case report journals in combination with open-access and dynamic databases could be possible avenues to creating new learning opportunities from case-based research.

Case reporting in action-oriented sustainability research – a way forward

Over the last two decades sustainability science has established a research field dealing with pressing global societal challenges. While the field has generated a wide spectrum of transdisciplinary, action-oriented and transformative approaches, the evolving research landscape is still characterised by division (Lang et al. 2017) and the focus on either context-specific research or research striving for generalisable results has created two separate communities (Lang et al. 2017).

The case reporting approach and the scheme we propose in this paper are clearly located in the former community, which recognises the local context as the arena where sustainability transformations can be collaboratively investigated through joint experimentation. However, while our case reporting scheme has been developed with the clear intention of fostering knowledge transfer between such cases, we also think it has the potential to contribute to bridging the aforementioned divide.

As argued by Lang et al. (2017), transdisciplinary (i.e. case-specific) and disciplinary (i.e. typically striving for generalisation) research approaches are equally necessary to contribute to sustainability transformations on a global scale. In our experience, published results from transdisciplinary research currently often address either highly specific aspects of a study or zoom in on results from analyses without adequately representing the overall character of the case study. Consequently, these results do not meet the expectations of either community as they are seen as being either too case-specific (and of little relevance beyond the individual case) or lacking in context (and therefore inadequate for knowledge transfer and/or learning) (Adler et al. 2018).

We see the case reporting scheme approach as a possible solution to the lack of a suitable format for adequately communicating the knowledge gained from transdisciplinary research and our scheme as a pragmatic tool for structuring the research conducted in ULLs and similar forms of transformative transdisciplinary and action-oriented research. We also consider our case reporting scheme a first proposal built on existing frameworks

in an attempt to reflect some of the contemporary understandings and concepts of the research field we are addressing. With the case reporting scheme, we hope to spark a discussion about how the field of action-oriented and transdisciplinary sustainability research communicates not only its results, but also its overall processes from which others can gain knowledge and inspiration.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s42854-023-00056-w>.

Additional file 1.

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Authors' contributions

Philip Bernert and Darin Wahl share the first authorship of this article and have contributed equally to the work. Henrik von Wehrden and Daniel J. Lang have jointly supervised and critically revised the work. All authors have read and approved the final manuscript.

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Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Declarations

Competing interests

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