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# Reading between the lines: a systematic approach to identifying underlying concepts in scientific literature – The case of interfaces between disciplinary lenses and real-world laboratory research

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**Abstract**

As settings for knowledge generation through experimentation and testing of 'solutions' to sustainability challenges in collaboration with various actors, real-world laboratories (RwLs) and related lab-based approaches have emerged across diverse fields of research. Although they already integrate knowledge from different disciplines and are receiving increasing attention in various academic disciplines and beyond, the interface dynamics that shape their work have yet to be explored. This presents two interconnected types of challenges that our paper seeks to address. First, conceptual and framing challenges arise concerning the positioning of real-world labs within this broader research landscape of experimental and participatory lab approaches, including questions of terminology and the relationship between more traditional disciplinary research and RwL research. Second, methodological challenges arise for conducting a literature review on this issue, including identifying rather underlying disciplinary contributions, recognizing novel approaches beyond established categories and defining suitable criteria for literature selection and synthesis. We argue that a combination of three approaches—bibliometric analysis, subject assignment and cluster analysis—can address both sets of challenges. By doing so, this paper pursues a dual objective: to provide a structured overview of the research landscape, thereby enhancing the understanding of interfaces and fostering learning processes between disciplinary lenses and RwL; and to reflect critically on the methodological implications of researching such a cross-cutting field. Results highlight potentials and pitfalls of identifying, mapping and analyzing underlying concepts and interfaces in scientific literature by "reading between the lines," providing a reference point for addressing similar challenges in other research domains.

**Keywords** Real-world labs · Literature review · Scientific mapping · Bibliometric analysis · Cluster analysis · Sustainability

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## Introduction

Faced with the need for new approaches to generating knowledge that can contribute to solving societal challenges in the "real-world," lab-based approaches have emerged in recent years as diverse, context-specific approaches that bring together multiple stakeholders to support the joint development of innovative solutions to complex challenges—for example, in the areas of urban development, sustainability or mobility (e.g., Bulkeley et al., 2016; Joost et al., 2025; McCrory et al., 2020). In particular in German-speaking countries, the term real-world laboratory (RwL) has become established for this purpose and is inspired by "transfer[ing] the concept of the laboratory, which is shaped by the natural sciences, to the analysis of social and political processes" and by doing so, providing a "social context in which researchers carry out interventions in the sense of 'real-world experiments' in order to learn about social dynamics and processes" (Schneidewind, 2014, p. 3). With numerous funding programs and its links to the academic community, real-world labs place particular emphasis on linking scientific inquiry to societal needs (Wanner et al., 2023). Beyond their conceptual grounding in the German context, real-world labs share similarities with broader international discourses on experimentation such as the notions of (urban) living labs or transition labs (Fraske, 2025; Kern & Haupt, 2021; McCrory et al., 2020). While this article takes RwLs as its conceptual starting point, it situates them within this broader landscape of these related lab-based approaches. Despite conceptual differences, they share the common feature of integrating diverse perspectives—including non-academic actors—to generate knowledge by testing, analyzing and further developing within "real-world" settings. These approaches are themselves grounded in a wide variety of theoretical frameworks (see Parodi & Steglich, 2021, p. 260). For example, they fit into the idea of experimentation or referring to an "experimental turn" (Evans et al., 2016; Schneidewind, 2014). They also take into account other strands of the debate such as transformative research and citizen science (Agnew et al., 2022; Heijmans & Eweg, 2023; von Gönner et al., 2023), Mode 2 research (Gibbons, 2000; Nowotny et al., 2001), post-normal science (Funtowicz & Ravetz, 1993), or action-oriented research (Logghe & Schuurman, 2017; Ståhlbröst & Holst, 2017). This highlights lab-based approaches are not emerging in a vacuum but already build upon, extend existing approaches and integrate knowledge from different research traditions.

However, the research field of real-world labs and adjacent approaches remains highly fragmented, shaped by a heterogeneous conceptual landscape (Schäpke et al., 2017). This applies both to the practical fields in which real-world laboratories are implemented and to the diverse academic approaches used to conceptualize and study them. The present article focuses on the latter: While RwLs are receiving increasing attention as transdisciplinary research and learning settings with specific methodological repertoires, the underlying disciplinary lenses, interface dynamics and connections to different research traditions that shape this literature remain underexplored. They can serve as analytical reference points for identifying the scientific contexts in which relevant concepts, methods, intervention logics, participatory formats and quality criteria are articulated. A better understanding of these interfaces can help to explore how RwL research can benefit from disciplinary resources and how, conversely, disciplinary and interdisciplinary research can learn from RwL settings of experimentation, co-creation, intervention and societal impact. Gaining a deeper understanding of these connections is essential—not only to situate real-world labs within a broader epistemic context, but also to draw on existing disciplinary knowledge for more effective integration into transdisciplinary practice (Weiser et al., 2023).[1] Tracing such conceptual patterns can be vital to understand how knowledge is produced, communicated and translated (e.g., Benckendorff & Zehrer, 2013; Cunningham et al., 2022).

Turning to a systematic literature review is a common strategy for mapping emerging or dispersed research fields (e.g., Boell & Cecez-Kecmanovic, 2015; Snyder, 2019). Yet, identifying a meaningful sample can be difficult, especially when the aspects of interest are not explicitly named in texts. Disciplinary lenses informing concepts, methodological repertoires or good practices may be implicit, distributed across different parts of the literature, or visible only by "reading between the lines." Addressing these gaps can provide a clearer overview of the field while uncovering linkages that foster mutual learning and collaboration. Against this background, several challenges emerge. For our case, this includes: (1) terminological ambiguity and the use of different terms to describe related lab-based approaches and (2) the need to better understand the interfaces between disciplinary and real-world lab research, including the mutual learning potentials between different research traditions and real-world lab approaches. On the other hand, in trying to grasp these challenges, we encountered a distinct set of methodological challenges related to literature selection and analysis, including (3) the difficulty of capturing novel or boundary-spanning approaches that may not yet be formally recognized within established fields; (4) balancing breadth and specificity, ensuring that the literature selection captures the broader landscape of lab-based approaches while remaining relevant to our research aims; and ultimately, (5) blind spots in the scientific contexts of RwL research, that is, identifying more underlying concepts that shape the literature but may not be easily captured through search terms. To address these challenges while exploring the interfaces between disciplinary research and real-world lab approaches, we ask:

> How can underlying concepts in scientific literature be identified and mapped out?

Following our initial research aim, we added a sub-question tailored to our specific case:

> How can this mapping help to understand both their interactions with and their influence on real-world laboratory research and vice versa?

To navigate this, we present and ultimately integrate multiple approaches to guide our literature selection and, for each of them, we discuss how they can help to identify relevant papers until a certain level of saturation is reached. In our specific case and with the objective of better understanding the mutual links between real-world lab and more disciplinary research within the broader research landscape, we argue that combining different approaches for mapping and systematizing the literature provides a structured foundation for further exploration of these links. Accordingly, using Scopus for a systematic literature review, we mapped a final sample of 402 peer-reviewed articles and book chapters in English through a threefold approach. We began with bibliometric analyses—including co-authorship for *authors* and a classification for *subjects*—and complemented this with a statistical semantic full-text analysis to cluster the literature into different *topics*.

[1] These core aspects of research guide the substantive work of the interdisciplinary working group *LinkLab*. The working group was established under the umbrella of the German Committee Future Earth (DKN) and aims to strengthen the theoretical and methodological foundations of RwL research and support its integration into diverse disciplinary contexts. The approach to the literature presented in this paper constitutes one step in this broader effort.

The paper continues as follows: in "Research design" section, we outline the research design, consisting of the three approaches and how we combined them to build a sample for in-depth analysis. In "Results" section, we start with an overview of the results for each approach before going into a more detailed discussion in "Discussion: identifying a meaningful sample for in-depth analysis" section. There we synthesize these insights, reflecting on what we have learned from combining the analyses of authors, subjects and topics. Although our overarching research question is addressed throughout the paper, Chapters 3 and 4 focus specifically on situating this contribution within existing strands of real-world lab research. Furthermore, we point towards opportunities for other research fields before presenting our concluding remarks in "Conclusion" section.

## Research design

### Strategic literature sampling

Several guidelines for conducting literature reviews already exist as well as different approaches, such as meta-narrative, integrative, critical, systematic reviews or mixed studies (Callahan, 2014; Davis et al., 2014; Jesson & Lacey, 2006; Liberati et al., 2009; Moher et al., 2009; Snyder, 2019; Wee & Banister, 2016). For instance, the integrative review synthesizes knowledge by incorporating diverse methodologies and sampling strategies, with attention to problem framing, analysis and interpretation, to build a comprehensive understanding of a specific topic (Shamrova & Cummings, 2017). The systematic review explores extant literature discussions, prior studies, knowledge gaps and theoretical frameworks on a specific research theme (Paul & Rialp Criado, 2020). Building on these different types, tailored frameworks have been proposed for fields such as international business and management (Paul & Rialp Criado, 2020; Tranfield et al., 2003), criminal justice (Denney & Tewksbury, 2013), political science and public policy (Knopf, 2006), psychology (De Klerk & Pretorius, 2019) and healthcare (Greenhalgh et al., 2004).

To better understand how disciplinary lenses shape RwL research as well as their interfaces within the broader landscape of adjacent lab-based approaches, we conducted a systematic literature review as “a method of making sense of large bodies of information” and “of mapping out areas of uncertainty and identifying where little or no relevant research has been done, but where new studies are needed” (Petticrew & Roberts, 2006, p. 2). The goal was to examine how and where such mutual links have already been established in the literature, including how the “lab” concept was framed and labeled and which methods, lab dimensions and overall practices were used.

As a first step, we used the Scopus database to identify peer-reviewed journal papers and book chapters that deal with real-world labs. We included both types of publications to capture a broader and more diverse range of perspectives. Following conceptualizations of real-world labs that argue for transitions to a more sustainable future (e.g., Schäpke et al., 2017), we deliberately limited our set to those that dealt with the topic of sustainability. In order to take into account the broader set of related approaches that address similar questions of experimentation, participation, intervention and (urban) transformation (see, for example, Liedtke et al., 2015; Nevens et al., 2013; Pereira et al., 2020; Schäpke et al., 2017; Voytenko et al., 2016), we included related terms in the Scopus search string. As a result, we applied the following search query: ‘living lab*’, ‘real-world lab*’, ‘transition lab*’, ‘transformation lab*’ AND ‘sustainab*’ including all articles with the search terms appearing in title, abstract or keywords. We searched for publications in English, resulting in a sample of 645 documents, published between 2002 and 2024. In the second step, we screened abstracts to assess each article's relevance, including only those that met the following criteria: (1) the publication integrates insights from concrete cases; (2) it explicitly engages with the concept or understanding of transdisciplinarity; and (3) it addresses both sustainability and the notion of a "lab" in a substantive way, rather than merely using them as catchphrases.

This abstract screening was distributed among the authors, with emphasis on fostering a shared understanding of the screening process to minimize bias. Accordingly, we tested the criteria on a small sample of up to 30 papers and collaboratively reflected on their relevance. In cases where a reviewer was uncertain about including or excluding an article, a second reviewer reevaluated the abstract—either using the established criteria or, if necessary, by consulting the full paper. After completing the abstract screening process, a total of 402 publications were selected for inclusion in the final sample, comprising 317 journal papers and 85 book chapters to which we refer to collectively as *articles*.

## Systematic sampling for in-depth analysis

In order to determine a saturated subset of papers from the initial set of 402 articles that would be suitable for qualitative in-depth analysis in a later stage, but still cover the relevant aspects from this diverse field, we combined three approaches on authors, subjects

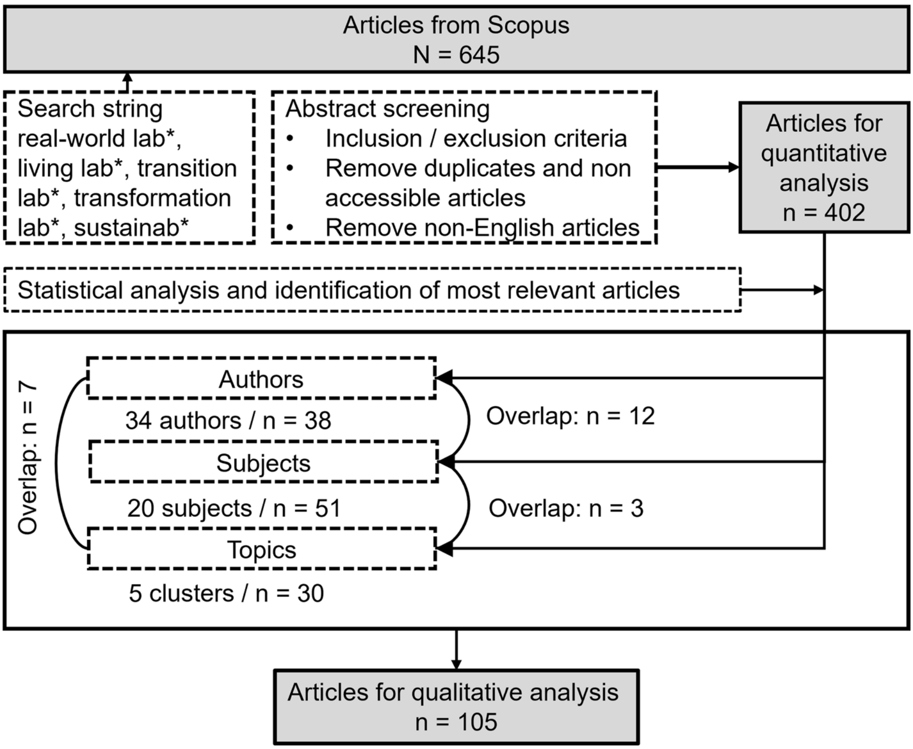


**Fig. 1** Research process for sample selection

and topics (Fig. 1). For authors, we conducted a co-authorship analysis; for subjects, we manually assigned research subjects to the articles; and for topics, we performed a semantic cluster analysis based on the downloaded full texts. Each of these approaches provides an overview of the research field and can be applied independently, yet they also open up various possibilities for engaging with disciplinary references in relation to our research question. Combining these approaches enables the analysis of larger data sets, particularly when further narrowing the literature sample might risk overlooking relevant contributions.

From these approaches, we extracted the *most relevant articles* based on sampling criteria aligned with our research objective and aimed at capturing the diversity within the respective cluster. Following our research aim, we included *articles from the core* of the main clusters—such as central author networks, dominant subject areas and representative papers within topic clusters—to reflect the "mainstream" of the field. Additionally, we selected *articles that were more isolated* or "at the clusters' edges" to also include potentially new perspectives from other disciplines (Sedita et al., 2018). In order to achieve a depth of content and theoretical saturation, we read and analyzed up to three articles per cluster in depth. This approach allowed us to systematically capture central concepts, recurring patterns of argumentation and methodological approaches while maintaining focus and preventing thematic fragmentation. This resulted in 38 articles from the authors cluster, 51 articles from subject assignments and 30 articles from cluster analysis of topics. Notably, there were several overlaps—papers that appeared in two or more of the samples generated by the different clustering methods—highlighting the interconnections of themes and contributors across the field. This combined approach ultimately led to a final sample of 105 papers selected for in-depth qualitative analysis in a later stage.

## Approaches to clustering: mapping authors, subjects and topics

To address the challenge of identifying a meaningful sample for an in-depth investigation—particularly given the limited explicit assumptions about the issue—we used a mix of quantitative approaches to analyze numerous articles in the diverse field as a first step. In the second step, we used the results to identify entry points for our analysis that would suit our research objective. As mentioned, this multi-pronged quantitative strategy was not only intended to ensure broad coverage but also to strategically inform a subsequent qualitative analysis. Thus, our approach can be better described as what Grant and Booth (2009) call mixed-method review as we selected specific articles due to the number of articles. By integrating quantitative and qualitative perspectives, these approaches enhance both the analytical depth and the practical relevance of literature reviews in fields marked by complexity and interdisciplinarity (Paul & Rialp Criado, 2020). The following sub-sections briefly introduce the approaches for authors (co-authorship), for subjects (manual assignment) and for topics (full-text cluster analysis). All analyses were conducted using RStudio, version 3.6.0.

### Clusters of authors: co-authorship analysis

An approach considered within the broader category of bibliometric analyses is analyzing the author landscape (e.g., Zupic & Čater, 2015). These analyses rely on bibliometric data (which encompasses various metadata elements, such as article title, sources, authors, affiliations, countries, abstracts, keywords and citations counts) and often involve methods like co-authorship and co-citation analyses. Both draw methodically on network analysis techniques for author analyses (Kumar, 2015, p. 56). And both indicate substantive connections between research topics, suggesting shared social (e.g., collaboration) and intellectual (e.g., conceptual or methodological foundations) connections in research. Furthermore, both methods are part of the most popular bibliographic methods (Ullah et al., 2022, p. 2f.). One of the main sources for acquiring bibliometric data is the Scopus database. Two prominent tools for conducting such analyses are VOSviewer and the R package bibliometrix (Lim et al., 2024, p. 2). While both tools are well suited for this type of analyses, we opted for R.

We then conducted a co-authorship analysis to explore collaboration structures within the research field by examining the networks formed through joint publications. In these networks, authors are linked via co-authored articles, allowing the identification of researchers or institutions that frequently collaborate and those who play central roles in the scientific community. This method reveals key players who significantly contribute to the development of the real-world lab field and help uncover the collaborative networks that shape knowledge production (Newman, 2001). In contrast, a co-citation analysis focuses on how often pairs of publications are cited together in other publications and is therefore mainly used to uncover the intellectual roots and canonical references of a field (Zupic & Čater, 2015). While co-citation analysis is valuable for mapping theoretical traditions, it would not have supported our aim of identifying relevant and current contributions within our sample or would have pointed our analysis toward older, highly cited works, while recent and potentially influential studies would have been less visible. Therefore, we focused on co-authorship analysis.

### Clusters of subjects: categorization with manual assignment

As a second step, we examined the subject-area contexts of the publications in our corpus. Subject classifications can help make visible how publications are distributed across subject areas and how different parts of a research field relate to one another. There are several systems used to classify scientific publications into recognized academic disciplines. These systems group research outputs based on their thematic focus, methodology or the journal in which they are published. They differ in depth (number of hierarchies), levels of granularity (number of categories at a level of hierarchy), level of multi-attribution (the number of subjects attributed to a single record) and scope (all science vs. subfields of science). A prominent classification system provided by Scopus is the *All Science Journal Classification* (*ASJC*) codes, which categorizes published research by its subject areas. This is done using the aims and scope of the title (e.g. journal) and the content that it publishes (Wang & Waltman, 2016). In 2021, Scopus organizes ASJC information into 27 distinct subject categories, including 1 specifically designated as a multidisciplinary category.

However, journal-based classifications also have limitations for the purposes of this study. Since journals may publish articles from different disciplinary backgrounds, the journal is not always the most appropriate unit for capturing the disciplinary context of individual publications (Abramo et al., 2018). Among others, Boyack and Klavans (2011) argue against the use of automated classifications based on journals and point out that “few journals are truly disciplinary” (p. 123). In addition, the choice of disciplinary classification can differ between databases (Sīle et al., 2021).

For this reason, we conducted a reclassification based on information about the institution of the first author, further affiliations as well as considering title and abstract. In a multi-stage process, each article was assigned to a specific subject. Following researchers such as Milojević (2020) and Gregory and Ninkov (2021), a manual reclassification, in which subject areas are assigned based on expertise, is common practice and recognized as both a highly accurate and particularly time-consuming approach. It also enables a more differentiated classification that can be tailored to specific research questions (Milojević, 2020, pp. 5–6). Rather than assigning RwLs or adjacent lab-based approaches to fixed disciplinary categories, we understand this approach as an analytical entry point for identifying the scientific contexts in which real-world labs are studied. In line with our research interest, this allows us to explore where conceptual and methodological resources, intervention logics, participatory approaches and quality criteria relevant to RwL research are articulated in the scholarly literature.

## Clusters of topics: full-text cluster analysis

With the emergence of big data analytics and machine learning tools, topic analysis has become an increasingly prominent approach to literature reviews, aiming to identify underlying themes based on semantic similarities within the text (Asmussen & Møller, 2019). Within analyzing semantic structures, there are different approaches such as topic modelling (Sharifi et al., 2025; Stefani et al., 2022) or semantic full-text cluster analysis (Abson et al., 2014; Engler et al., 2024; Rathgens et al., 2020; Weber et al., 2020). While some of the approaches—similar to the bibliometric methods mentioned in "Clusters of authors: co-authorship analysis" section—are limited to metadata such as keywords, abstracts, or titles, cluster analysis enables content categorization based on semantic similarities within the full text. This approach allows for the identification of thematic structures, recurring topics and latent concepts that are not explicitly captured by traditional classification systems or search strategies. Methodologically, cluster analysis identifies groups of publications by detecting similarities in word usage patterns, based on the assumption that texts discussing related topics tend to employ a shared vocabulary (Weber et al., 2020, p. 3). Especially for interdisciplinary research fields, where different terminologies and theoretical approaches coexist, this method offers the possibility of establishing new connections between disciplines and identifying unrecognized research niches.

The full-text cluster analysis reveals thematic and problem-oriented patterns that go beyond surface-level keywords and metadata. It therefore allows us to explore how disciplinary interfaces relate to topics, shared concepts and problem-oriented themes in the literature. This approach is particularly well suited to our research objective, as it uncovers deeper thematic structures that are not apparent through traditional metadata analysis. To do so, the full texts of the articles were downloaded, imported into R and the text was analyzed. In order to filter out rare vocabulary, only words that appeared in more than 5% of the publications were included for co-abundance analysis and clustering (e.g., Engler et al., 2024, p. 4). Based on this, we performed Ward clustering. This is a hierarchical clustering method that groups elements (in our case, articles) based on minimizing the variance within each cluster (e.g., Jaeger & Banks, 2022, p. 5). Within-group variance was considered as low if a similar set of words was used in the articles. Similarly, the dissimilarities between groups were high when each community had a distinct set of vocabulary.

## Results

We adopt an integrative strategy that combines author-related, subject-area and thematic perspectives, that enables us to triangulate our findings and construct a more comprehensive sample by selecting papers identified through the convergence of these complementary analyses. Rather than treating these perspectives as merely technical steps in a methodological procedure, we use them as analytical entry points into a heterogeneous scholarly field: they allow us to examine how RwL research and adjacent lab-based approaches are structured through collaboration patterns, scientific publication contexts, and thematic or problem-oriented clusters. Our results are organized into such three main sections, each examined through a common framework: an overview, an analysis of conceptual diversity and an exploration of the center and core literature as well as the periphery (or edge). This structure allows us to systematically identify key concepts and distinguish between central and more marginal contributions within the field. This structure allows us to systematically identify key concepts, methodological repertoires and potential blind spots, while also distinguishing between established and more marginal contributions within the literature. Throughout these sections, we detail what we "read" (i.e. which articles became part of our sample for further in-depth analysis) from each approach, showing how this guided our engagement with the literature. In this way, we show how the methodological framework shaped our understanding of the intellectual landscape and how it can support further qualitative and conceptual investigation of RwLs and adjacent lab-based approaches.

### Authors

#### Overview

The analysis reveals that the 402 articles in our sample were authored by a total of 1500 individuals, averaging four authors per paper, which indicates a high level of collaboration (e.g., Wuchty et al., 2007). Building on this observation, the subsequent co-authorship analysis maps out the collaborative networks and indicates which authors and institutions are particularly active and how they work together. In order to reduce the number of authors for the consideration of the co-author network and against the background that the authors deal with the RwL topic more intensively and not only occasionally, we defined a minimum number of publications of at least three. This also helped us limit the articles for the subsequent qualitative analysis. As a result, 34 authors met the threshold. The visualization (Fig. 2) shows an author landscape that identifies three large clusters, with 10 authors outside those clusters and also not connected to each other (except 2, which are connected in pairs each).

#### Conceptual diversity

Taking a closer look at the key players (frequently cited or networked researchers) in the field, they come largely from Germany (Cluster 2 (blue) and Cluster 3 (green)), Sweden and the Netherlands (Cluster 1 (yellow)). This pattern points to the close connection between the literature captured in our corpus and debates on sustainability and transformation research. The strong presence of German-based authors should also be read in light of the real-world lab term, which makes Germany a particularly visible context in the author network. Of particular interest is the role of sustainability transitions as a theoretical

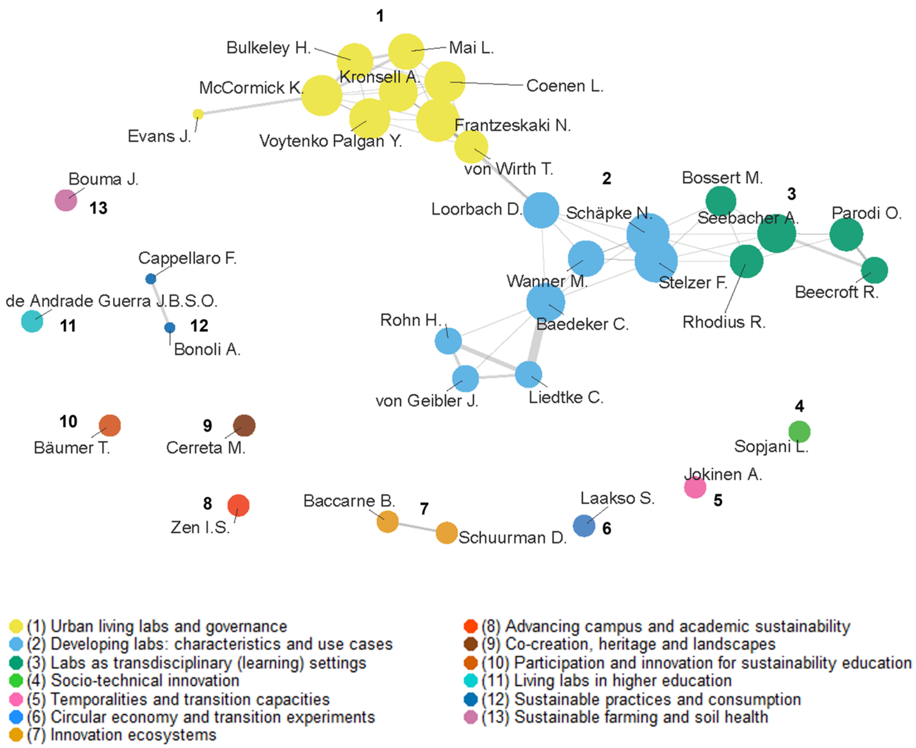


**Fig. 2** Co-authorship network showing authors with at least three publications. *Note* Co-authorship analysis based on authors with at least three publications in the sample. Node size reflects publication frequency. The network includes 13 authors or clusters of authors, each numbered and labeled according to the dominant research focus within their body of work

framework that spans several clusters. It is mobilized both in studies on the governance of ULLs and in work on sociotechnical and socioeconomic transformation processes. Despite their different origins, the clusters also suggest that there are connections through shared conceptual resources and bridging actors. For example, von Wirth co-authored a publication with Loorbach on the role of co-creation in urban transition governance (von Wirth et al., 2020), while Loorbach also contributed to Schäpke et al. (2018), an article outlining the key characteristics of real-world labs. Alongside Bergmann et al. (2021), which focuses on identifying success factors for RwLs, both articles serve as important bridges between author clusters, linking otherwise more distinct strands of lab-based research. Additional notable bridge builders include Baedeker, who uses the term of living lab and spans connections to innovation and design; and both Rhodius and Seebacher, who have frequently shared insights from a diverse range of RwL projects they were involved in, primarily in Germany.

## Navigating center and core

In line with our research aim, we paid particular attention to both conceptual centers and edges. In practice, we read up to three articles from each cluster, including actor networks and established actors without connections. To limit the number of articles for qualitative analysis and since the three bigger and connected networks have an overall larger number of articles, we read one article by a marginal author, one by a central author and one article by a bridge builder. The links between the three big author clusters can be explained not only by cooperation, but also in terms of content and methodology. For example, there is a close connection between work on urban governance (Cluster 1 (yellow)) and on sustainable urban development (Cluster 2 (blue)). Both deal with questions of how experimental governance models, in particular Urban Living Labs (ULL), can be used as instruments for managing transformation processes. Cluster 1 is strongly characterized by governance and planning research, with a focus on institutional embedding and policy frameworks. Cluster 2 is more oriented towards social science and interdisciplinarity, with a particular interest in participatory processes and social change while assessing and improving real-world laboratories as well as the institutionalization of the RwL concept, which makes Germany a particularly visible context in the author network. Cluster 3 (green) is more grounded in pedagogy and educational approaches and examines real-world laboratories as spaces for experimental learning and knowledge exchange. They often explore new connections between disciplines (in this case, for example, arts, management, soil science) or propose alternative methodological approaches.

## Subjects

### Overview

Examining the subjects follows a similar logic, as it allows us to examine the scientific publication contexts in which the literature is situated. Rather than treating subject areas as fixed disciplinary anchors, we use them as analytical entry points for identifying the relative visibility of different research contexts within the corpus. Less prominently represented subject areas may be particularly relevant, as they can point to conceptual and methodological resources that are less visible in the dominant strands of the literature. Scopus assigns multiple subject areas to individual articles, resulting in a total of 931 subject assignments across our sample. Of the articles analyzed, 340 were assigned to more than one subject area, while 29.35% were assigned to a single subject. Overall, the social sciences emerge as the dominant disciplinary link to real-world laboratory research and is frequently mentioned together with environmental science. However, given the limitations of this automated subject assignments, we conducted a manual reclassification of each article, as shown in Fig. 3.

### Conceptual diversity

This more refined approach confirms the prominence of social sciences and environmental topics, but also highlights other important fields. These include urban and regional planning, architecture and engineering. Subject frequency ranges from isolated cases (e.g., arts and biology) to 65 occurrences for environmental and sustainability research. Other subjects with high frequency were urban and regional planning and cultural and social sciences. Additionally, we identified distinct subject areas such as food research and mobility research, as some articles explicitly address these topics within dedicated research institutions. Overall, we identified 20 subject areas, providing a more nuanced picture. Since the assignment was developed through a multi-step process, the categories could also be

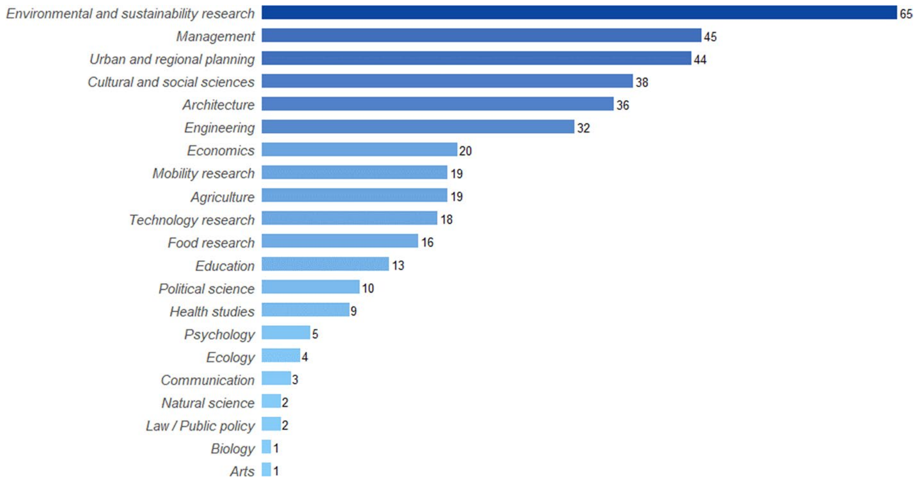


**Fig. 3** Assigned subject categories and number of articles for each category

further refined or aggregated depending on the analytical focus, for example by distinguishing whether food research is primarily linked to economic aspects or policy. In our sample, food research often reflects systems thinking and aims to optimize the food system. In one example, they apply a coupled systems approach to address the manifold and interlinked challenges related to doing second-order ('how to') transformative research that contributes to food systems transformations. They highlight the need for a coupled-systems perspective to realize double transformations in both R&I systems and food systems ('how to do the "how to"') (Kok et al., 2019). Another study explores experimenting with intervention designs for more sustainable food choices (Langen et al., 2022). While assignments are clearer for some subjects, e.g. education, where the literature engages with studies examining campuses as living labs or emphasizing co-production and sustainability transitions, while others explore learning processes through a systematic education-for-sustainable-development framework. In other areas, research is often better understood as topic-driven than through assignment to a specific discipline. For instance, in technology research there are articles with a strong focus on technologies, which utilize, for example, a smart stadium as a living lab approach to conduct data-driven projects with the aim to improve safety (crowd understanding), fan engagement (athletic demonstrator platform) and efficiency/convenience (wait time/queue estimation) (Panchanathan et al., 2017). Others frequently integrate social science theories and methods to investigate complex, human-centered phenomena. For example, one study uses the theory of practice to explore behavioral change in energy consumption (Matschoss et al., 2021). Others investigate user involvement (Sauer, 2012) or actor roles in open innovation contexts (Schuurman et al., 2016). Similarly, articles in agriculture often combine several knowledge domains. Wolfert et al. (2010), for example, examine how information and communication technologies can be organized to support a knowledge-based agri-food economy, combining elements from agricultural science, information systems and economics.

## Navigating core and periphery

These results underline both the value and the limitations of the chosen method. It allowed us to visualize subjects and classify the articles. At the same time, it revealed the interdisciplinary structure of many contributions: research on RwLs is often thematically driven and crosses methodologically as well as theoretically established disciplinary boundaries. Many studies, although situated in particular subject areas, often draw on theories, methods or problem framings from other domains and are shaped both by disciplinary affiliations and by the topics they address. These examples illustrate why it is also useful to interpreted subject-assignment together with thematic and problem-oriented approaches to literature. However, the classification shows where previously less represented subjects could be conceptually connected. For the subjects, we read the three most cited articles from each subject (for some subjects, there were just one to two articles, which we also included) to cover underrepresented subjects as well. Individual articles in our sample suggest that concepts from biology, public policy or communication could play a role in shaping or understanding transformations—for example, in the context of food systems or urban resilience. The classification therefore also makes it possible to identify further blind spots and development potential within the research field—both in terms of disciplinary involvement and theoretical and methodological connectivity. In this way, it also shows what is rarely or not at all represented, such as ethics, philosophy, history or law.

## Clusters of topics

### Overview

Based on the semantic full-text analysis, we identified five more or less distinctive clusters within the research field of sustainability-oriented real-world laboratory research. Although our analysis identified five clusters, with an agglomerative coefficient of 0.83 (0.8269142), the clusters overlap to a certain degree, which indicates the use of similar words. However, a first set of the most relevant key terms already indicates the content of the cluster as well as the differences (Table 1).

The following illustration shows the five clusters and their overlaps (Fig. 4, bottom right). The dots indicate the position of each article and indicate the ID of the articles.

**Table 1** Top 10 key terms that define each cluster

| Cluster (Number of articles) |
|---|
| a: Living Labs as catalysts for energy efficiency and sustainability (52) |
| Energy Solar Packaging Car Heating Comfort Electric Heat Travel Temperature |
| b: Fostering smart cities (199) |
| Smart Food Campus Urban Mobility Heritage Digital City Water LLs |
| c: Sustainability pathways for urban development (90) |
| ULL RwLs RwL ULLs Transdisciplinary Urban Realworld Transitions Transformative Experiments |
| d: University-Driven Sustainability through Living Labs, Waste Minimization and Education (55) |
| Campus Waste Students Teaching Education Campuses Brazil Universities Sport SDGs |
| e: Transdisciplinary approaches to promote soil health and biodiversity (6) |
| Soil Soils SDG Biodiversity SDGs Farmers Ecosystem Threshold Farm Organic |

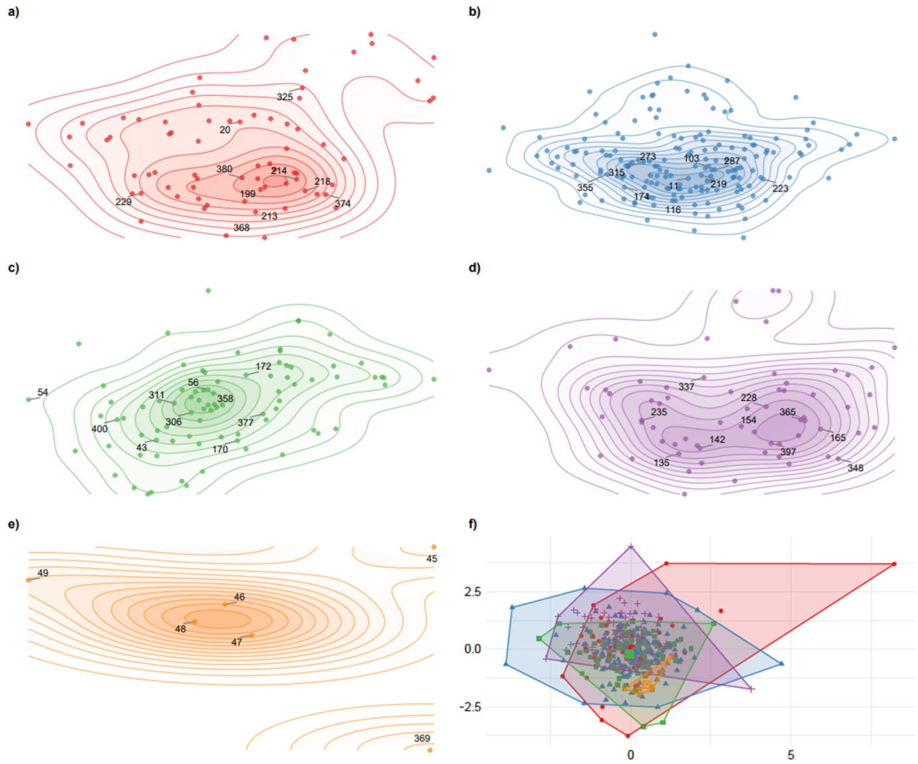


**Fig. 4** Cluster analysis: visualization of the five identified clusters and their overlaps. *Note* the main plot shows the clusters spatially arranged, with each cluster labeled accordingly [e.g., Cluster (a) top right, Cluster (b) top left, etc.]. The inset at the bottom right depicts the overlap across clusters. The (numbered) nodes represent the individual articles from our sample and refer to the article IDs

## Conceptual diversity

Articles in **Cluster (a)** which we named based on the terms and content “Living labs as catalysts for energy efficiency and sustainability” focus on the interplay between architecture, engineering and behavioral research. Energy is the most prominent term in this cluster. The studies center on energy efficiency, built environment as well as sustainable practices, with frequent references to smart technologies, particularly those related to data management, systems optimization and mobility practices. For example, studies in this area investigate how design interventions in built environments can enhance energy efficiency. Insights from behavioral science are applied to influence user actions, for instance through feedback systems or adaptive control mechanisms (e.g., Baedeker et al., 2020; Matschoss et al., 2021; Schwartz et al., 2015), while others draw on more social science-oriented analyses such the role of milieu research (Buhl et al., 2016). **Cluster (b)** mainly deals with the integration of digital technologies into sustainable systems. The focus is on cities, a few contributions are from university living labs (e.g., “tech campus”). Research articles from economic and urban development with an emphasis on technological development [e.g., R&D, circular city, smart city, (open/user driven) innovation] are characteristic for this cluster. Disciplinary differences become particularly apparent in the design and evaluation of such technologies. While more technology-oriented papers tend to emphasize the development and acceleration of innovations (e.g. Andersson & Rahe, 2017), social sciences focus on aspects such as acceptance, barriers to adoption and multi-stakeholder collaboration (e.g., Innerhofer et al., 2022), as well as cases that integrate these perspectives (e.g., Trombadore & Balocco, 2021). In **Cluster (c)** the term "real-world laboratories" is well represented. However, the articles are not limited to the term of real-world labs; rather, they are linked by an understanding of labs as transdisciplinary research approaches or research settings, analyzing their key characteristics—such as co-creation, experimentation and transformative research—and evaluating their impact, particularly through comparative studies of different lab initiatives. The articles in this cluster emphasize governance and urban research approaches to transforming urban spaces, but placing the focus on questions of governance, urban planning and socio-ecological sustainability and, in particular, the role that research can play in this regard (e.g., Bulkeley et al., 2016; Frantzeskaki et al., 2018; Hajer & Versteeg, 2018). Governance approaches benefit from real-world laboratories because they can interact directly with stakeholders and test policy designs for practicability. At the same time, urban researchers gain access to real decision-making processes, which provides new insights into institutional persistence tendencies and transformation mechanisms. Differences can be seen in the fact that disciplinary frameworks often play a role in the structuring of participation processes, while evaluation is often practice-driven and geared towards concrete urban challenges (Pärli et al., 2022; Parodi et al., 2018; Schäpke et al., 2018). **Cluster (d)** focuses on lab-approaches as spaces for learning processes and transformative education. Studies in this cluster originate primarily from the educational sciences and sociology. For example, in understanding the campus as a living lab and conceptualize it as a framework, which includes both learning on the one hand and increasing sustainability on the campus, on the other hand (e.g., Evans et al., 2015). One example is the development of sustainability-oriented educational formats at universities, in which students analyze real-world challenges and develop proposed solutions in such lab settings. This shows that the discipline has a strong influence on the design of real-world laboratories, as learning objectives, methods and evaluation criteria are often derived from educational theory concepts. At the same time, "transdisciplinary living labs" enable educational researchers to test and further develop theories on transformative learning processes (e.g., Crosby et al., 2018).

## Navigating center and core

For in-depth analysis, we included the most central articles within each cluster as indicated by statistical analysis. We also paid attention to the three more peripheral works that span the edges of each cluster, allowing us to examine conceptual overlaps and less dominant perspectives. A noteworthy aspect of the cluster analysis is that the clusters themselves represent a classification—some represent the core of the discourse, while others reflect more marginal strands. For instance, **Cluster (e)** can be interpreted as a peripheral thematic cluster. It is characterized by an ecological and agronomic perspective, which is closely linked to soil management and sustainable agriculture. The works examine the importance of soil quality and biodiversity and focus is on quantifiable indicators such as soil fertility, carbon sequestration and water retention. With references to the Sustainable Development Goals, they also address implementation, e.g. action plans or alternative agricultural practices that integrate social, economic and ecological aspects. The transdisciplinary perspective includes, in particular, agricultural research and the focus is not necessarily on the civilian population, but rather on the different expertise of farmers and biologists. As this cluster includes a small number of articles of the same direction, there are limited differences within the cluster. In the case of the other clusters, the peripheral work uses other use cases, for example, by focusing on future homes (Keyson et al., 2017) resp. having a more design-driven background (Femenias et al., 2016) or testing how modeling and simulation techniques can help for problem-solving in living labs by exploring different passenger behaviors and their causes with a main focus on improving the algorithm (Choi et al., 2021).

## Discussion: identifying a meaningful sample for in-depth analysis

### Sampling in practice: insights from real-world labs and navigating approaches

#### Conceptual diversity in real-world lab research

Our analysis shows that the literature captured in our corpus has a recognizable conceptual core relevant to RwL research, but should not be understood as a homogeneous field. This core is strongly shaped by social science perspectives, urban questions and governance debates and real-world labs are also commonly researched as a format for education and learning. At the same time, the results show both RwL-specific contributions and adjacent work on (urban) living labs, transition labs and transformation labs. These strands overlap around shared concerns with experimentation, participation, learning, intervention and transformation. Notably, terms included in our search strategy should not be understood as synonymous with RwLs as they may differ in conceptual origins, actor constellations, institutional settings or the role attributed to academic research. This diversity of the field is not only a challenge, but also a resource for RwL research as they make different aspects of RwLs visible: some foreground institutional and governance arrangements, others emphasize transformation processes, actor constellations, everyday practices or methodological questions of intervention and learning across different lab-based approaches. However, it also requires more explicit reflection on which concepts are used, what they foreground and what they may leave aside.

#### Disciplinary lenses reveal resources and blind spots

The mapping provides first indications how underlying disciplinary lenses may become visible. The limited overlap between the analytical clusters underlines the value of combining several methods. Many articles appear only in one analytical perspective, indicating that each approach captures different dimensions of the field. Author clusters show how parts of the literature are connected through collaborative structures and shared reference points. Topic clusters illustrate different strands of lab-based research, ranging from technology-oriented approaches and environmental indicators to social science-oriented work on urban transformation, social practices and participation. Subject assignments, in turn, help identify visible publication contexts as well as less represented areas such as psychology and law. These lenses can help real-world labs theorizing interventions, designing participatory processes, assessing learning and transformation, reflecting on researcher roles and developing quality criteria for situated and collaborative knowledge production. At the same time, the relationship is not one-directional. RwL research may also inform disciplinary debates by foregrounding situated intervention, co-creation, transdisciplinary collaboration, societal impact and reflexive forms of knowledge production. On a side note, a more recent publication on regulatory experiments and real-world labs, for example, indicates growing attention to legal and regulatory interfaces (Bauknecht & Kubeczko, 2024).

### Core and periphery as starting points for further engagement

The distinction between core and peripheral literature is particularly useful in this context. Core contributions help identify shared reference points and established vocabularies within the field. Peripheral contributions, by contrast, may point to less visible but potentially important resources. Examples include approaches such as "urban acupuncture," which conceptualizes systemic change through small, targeted interventions (Robaeyst et al., 2021), or psychological perspectives that may help analyze participation, motivation and actor interaction in lab settings (Zimmermann et al., 2018). Such contributions can indicate where RwL researchers and disciplinary communities might engage more deeply with one another.

### Shortcomings and limitations of the mapping for RwL research

These insights have to be interpreted in light of the scope of the study. Our focus has been on developing a strategy for identifying relevant literature within a heterogeneous corpus and on describing the overarching structure of this corpus through selected insights. The results should therefore be read as a ***preparatory step*** rather than as a complete conceptual synthesis, providing insights but also indicating where closer reading may be particularly fruitful. Furthermore, the article focuses on ***scholarly publications***, as our goal is to examine the scientific contexts in which RwLs and adjacent lab-based approaches are being researched. This focus is suitable for identifying disciplinary interfaces in the academic literature, but it does not capture the full range of practical, policy-oriented and project-based knowledge production surrounding lab-based approaches such as conference proceedings (e.g., Jansen et al., 2022), working papers (e.g., Bauknecht et al., 2019), or project reports (e.g., Libbe & Marg, 2021), which often present early insights or practice-oriented developments that may not yet be formally published. Moreover, the corpus reflects the broader landscape of real-world, experimental, participatory and transformation-oriented lab approaches rather than a narrowly defined RwL literature. While this is useful for identifying overlaps, bridges, and resources, it requires caution: the results should be read as a mapping of a wider scholarly landscape in which partly distinct lab-based literatures intersect. The ***terminological and conceptual diversity*** surrounding real-world labs is broader than the set of terms included in our search strategy. Numerous related terms—such as regulatory experiments (Bauknecht et al., 2019), regulatory sandboxes (Attrey et al., 2020) or city labs (Iaione, 2017)—explore similar phenomena or overlapping logics, yet they are often framed under different conceptual umbrellas. For example, the article from Iaione (2017) about "urban rights to pooling" introduces legal tools that can formalize and protect collaborative practices within RwLs, providing a normative and institutional foundation for long-term transformation. This heterogeneity makes it difficult to capture the full range of relevant literature using predefined search terms alone. The term experiment, in particular, illustrates this ambiguity: while central to RwLs, it is widely used in unrelated fields such as medicine (McCrory et al., 2020, p. 3) and appears in other contexts—like rural development (e.g., Peña-Torres & Reina-Rozo, 2022) or psychology (Bögel et al., 2023)—where it is not directly associated with laboratories, yet may still offer relevant perspectives. This diversity presents a challenge, but also reinforces the methodological choice not to rely solely on a search-string-based sampling strategy and to opt for a broad iterative and integrative approach. Moreover, our analysis was based on the Scopus database and we used relational indicators—such as citation frequency—to select the main author contributions as well as central papers in subject assignments for in-depth analysis. This process was therefore limited to some extent by ***impact factors*** and did not capture the full breadth of ***scholarly output*** (Zupic & Čater, 2015). On a last note, our mapping identifies the core of the field, its margins and selected points of connection where underlying disciplinary lenses may be explored in greater depth.

## Sampling as strategy: insights for broader application

While the previous section explored how our combined approach unfolds within the context of real-world laboratory research, the following section shifts perspective to examine how this strategy can inform broader conceptual and methodological work. We outline key takeaways for researchers aiming to identify conceptual structures in other fields, as well as practical considerations for adapting this sampling logic beyond our case.

### Combining approaches supports reflexive sampling

A key lesson from this study is that mapping a research field does not simply reveal a pre-existing structure. Different analytical approaches make different forms of relevance visible which has direct implications for literature reviews. Depending on the aim of a review, focusing on the most cited, most connected or most thematically central publications may be entirely suitable, for example when the objective is to reconstruct dominant debates or established knowledge structures. However, when the aim is to identify implicit conceptual orientations, less visible resources, blind spots or contributions at the margins of a field, such a strategy may reproduce dominant strands while overlooking conceptually relevant but less central publications. In our case, while articles at the edges of topic clusters often lacked internal diversity, but made different terminologies visible in outstanding clusters, author networks offered new conceptual impulses and subject assignments helped identify what is emerging, but also what is missing (see also Lim et al., 2024).

### Limitations of individual approaches justify their combination

The limitations of the individual approaches are central to this argument. Author-based analyses, for instance, tend to emphasize well-cited or networked researchers, which may overshadow emerging ideas and provide limited insight into the actual content of the research. In addition, the number of authors considered is typically restricted—either by focusing on those with a certain number of publications or those embedded in dense collaboration networks (Zupic & Čater, 2015, p. 4). Subject-based classifications, while helpful in mapping the research areas, still rely on interpretive judgments based on limited information and may miss interdisciplinary nuances (Gregory & Ninkov, 2021). Topic clustering, in turn, captures thematic patterns and problem-oriented domains but is sensitive to textual quality and less effective in revealing intellectual networks. Additionally, different methodological choices influence outcomes: some studies include all words in the analysis, while others restrict inputs to specific word classes such as nouns (Engler et al., 2024; Rathgens et al., 2020; Weber et al., 2020). Both author and subject analysis depend heavily on metadata quality (e.g., author affiliations, keywords, citations), which is often inconsistent or incomplete across publication formats. These limitations do not undermine the value of the individual approaches. Rather, they show why their combination can be analytically productive. On a side note, a further advantage lies in the integrative potential of the different analytical dimensions. Subject categories, for example, can be visualized and analyzed not only within semantic clusters but also across co-authorship and citation structures—yielding a multi-perspective view on a field's internal dynamics. This can be especially valuable for strategic research design, funding allocation or policy-oriented syntheses.

### Mapping as preparation for qualitative synthesis

At the same time, our approach does not stop here by highlighting the combination of various approaches and focusing on tracing the general development of a research field (e.g., Bernatović et al., 2022; Manyani et al., 2024). By contrast, we argue linking quantitative mapping with interpretative depth can support a more transparent and comprehensive sampling strategy and provide a solid foundation by identifying where close reading may be most fruitful. This is especially relevant for research fields that are fragmented, conceptually diverse or characterized by overlapping terminologies. Reading up to three articles per cluster proved sufficient in our case as recurring patterns indicated a level of theoretical saturation. The selection strategy, informed by recurring topics, methods and theoretical frameworks, proved suitable for the content-focused, qualitative nature of our analysis (see also Rathgens et al., 2020). This included sampling articles from both the core and edges of the field—drawing on network theory (Granovetter, 1973), we assumed that innovations often arise at the margins. Our method allowed us to identify and compare central and peripheral articles across all three analytical dimensions—authors, topics and subjects. Depending on the research field, it may be useful to select different subject classifications or grasp the subjects at different levels of granularity.

## Conclusion

Our research was motivated by the interest in better understanding the mutual relationship between disciplinary lenses and the scholarly literature on real-world laboratories (RwLs) and adjacent lab-based approaches. Because such lenses are often not explicitly named and cannot be captured through search terms alone, we developed a literature sample by combining three complementary approaches: author analysis, including co-authorship analysis; subject-area assignment, based on manual reclassification; and thematic full-text cluster analysis. We argue that these approaches complement each other by bringing together social, more explicit disciplinary and content-related perspectives on scientific texts. Since the primary objective was to map out rather underlying concepts, our results can ultimately serve as a "starting point for reading," offering guidance from multiple perspectives to navigate a broad and diverse body of research. This represents the first level of our contribution, focused on mapping and orientation.

On a second level, our study moves beyond bibliometric mapping and clustering by providing empirical insights into ongoing developments and research practices in real-world laboratory contexts. By describing the overarching structure of this corpus through selected insights, it contributes to the broader discourse on how RwLs are conceptualized, implemented and evaluated across different domains. First, the author analysis shows a core group of researchers, connected through conceptual backgrounds such as transition theory, governance as well as urban research and joint projects. At the same time, our research made ‘invisible colleagues’ and networks visible. Second, the subject classification highlights both existing interdisciplinary overlaps and potential for development through the identification of blind spots such as ethics, philosophy, history and law. Third, the cluster analysis reveals five distinct research foci: from energy efficiency and sustainability and digital technologies in sustainable systems to real-world laboratories as social interfaces, as spaces for transformative education and sustainable agriculture, where real-world labs primarily serve as settings to facilitate these goals. Each approach shows how they identify different articles as relevant. Across the approaches, the field of research shows a dominant social science core and a strong urban focus, while the different methodological approaches offer complementary perspectives and identify valuable marginal concepts such as urban acupuncture, design-related approaches or legal approaches that have not yet been fully integrated into the academic discourse for each of the mapping approaches. In doing so, our analysis extends beyond mapping disciplinary interfaces to tentatively explore aspects of academic culture and practice within the field and offers valuable insights into fruitful links between disciplinary lenses and real-world lab research and for further exploring these links in greater qualitative depth.

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## Declarations

**Conflict of interest** The authors declare that they have no conflict of interest.

**Ethical approval** Not applicable.

**Informed consent** Not applicable.

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