

Review Article

Cite this article: Harris F, Lyon F, Sioen GB, Ebi KL (2024). Working with the tensions of transdisciplinary research: a review and agenda for the future of knowledge co-production in the Anthropocene. *Global Sustainability* 7, e13, 1–13. <https://doi.org/10.1017/sus.2024.11>

Received: 6 July 2023

Revised: 19 January 2024

Accepted: 1 February 2024

Keywords:

collaboration; institutional logics; sustainability science; transdisciplinarity

Corresponding author:

Frances Harris;

Email: f.harris@herts.ac.uk

Working with the tensions of transdisciplinary research: a review and agenda for the future of knowledge co-production in the Anthropocene

Frances Harris¹ , Fergus Lyon² , Giles B. Sioen^{3,4}  and Krsitie L. Ebi⁵ 

¹Geography, Environment and Planning and School of Education, University of Hertfordshire, Hatfield, UK; ²Centre for Enterprise Environment and Development Research, Middlesex University, London, UK; ³Future Earth Global Secretariat, Tsukuba, Japan; ⁴Earth Systems Division, National Institute for Environmental Studies, Tsukuba, Japan and ⁵Center for Health and the Global Environment (CHaNGE), University of Washington, Seattle, WA, USA

Abstract

Non-technical summary. Transdisciplinary approaches for sustainability brings natural and social science researchers together with non researchers to fill gaps in scientific knowledge and catalyze change. By connecting diverse academic fields and sectors, it addresses complex problems and enables learning for problem solving. However, institutional barriers, funding constraints, time limitations, and evaluation criteria hinder collaborative progress. Our review reveals tensions at institutional and individual levels. Our findings underscore the significance of soft skills in assembling effective transdisciplinary teams. Embracing transdisciplinary science, as suggested by our review, can enhance problem-solving, and foster transformations for sustainability and resilience.

Technical summary. Sustainability challenges in the age of the Anthropocene require researchers and practitioners to collaborate across multiple academic disciplines and multiple professions outside of universities. In this paper we draw on theories of institutional logics to explore how those involved in transdisciplinary environmental research and practice draw on particular sets of values and norms but encounter challenges to collaboration. These institutional logics include (among others) seeking societal/environmental impact, commercial objectives, and academic knowledge generation. In this paper we review the growing literature on the research experience of transdisciplinarity in sustainability; discuss the processes of managing such research; and present a framework that outlines the challenges and tensions at each stage of the innovation/research process. We set out an agenda for managing tension that calls for recognizing the challenges, learning how to work with tensions, and building capabilities for future careers involving transdisciplinary research. The paper shows a key competence or skill for transdisciplinarians is the ability to develop complex collaborative relationships for sustainability drawing together different institutional logics, approaches, methods, goals, and values.

Social media summary. Transdisciplinary science: bridging disciplines, solving challenges. Soft skills and collaboration key to success.

1. Introduction

Societies are increasingly beset by complex wicked problems that require input from a range of academic disciplines and professional practices to prepare for and effectively manage the challenges of the Anthropocene. Such collaborations have been said to require ‘transdisciplinary efforts to generate the understanding needed to underpin robust policy decisions for human and planetary health’ (Ebi et al., 2020). Managing complex problems requires systems-based approaches that transcend disciplinary compartmentalization, identifying solutions that address changes in the context of ongoing social, economic, and political change, and recognizing the interconnections across, for example, the 17 Sustainable Development Goals (Hills & Maharaj, 2023; Wardani et al., 2022). The search for ways of flourishing within environmental limits (Jackson, 2017) and earth system boundaries (Rockström et al., 2003) cannot be left to single disciplinary specialists. There are calls to bring different perspectives and disciplines together to solve problems that are complex and interdependent (e.g. Wuelser & Pohl, 2016). The projects require a focus on systemic change, rather than isolated missions (Lieberknecht et al., 2022). This is resulting in a growing recognition of the need for transdisciplinary collaboration involving representation from multiple disciplines and practice (Hölsgens et al., 2023; Norris et al., 2016).

Applying science to solve environmental problems of the Anthropocene in ways acceptable to society also requires aligning the goals of research, policy options, and public acceptability. People who can work across disciplines and across sectors (academia, government, business, community groups, public) have been termed transdisciplinarians.

© The Author(s), 2024. Published by Cambridge University Press. This is an Open Access article, distributed under the terms of the Creative Commons Attribution licence (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted re-use, distribution and reproduction, provided the original article is properly cited.



Transdisciplinary science has been promoted for over 20 years; yet researchers adopting its methods often have to contend with challenges due to misconceptions and the institutional structures under which researchers function (Shackleton et al., 2023). Transdisciplinary research processes are more complex because research team members negotiate goals, priorities, problem framing, research approaches, methods, and stakeholder input prior to collecting data (Crowston et al., 2015; Lang et al., 2012). Justice and all its components within transdisciplinary projects are also brought to the foreground. Who is part of a project and who is not? Who is it for and who might be impacted by its implementation? (Juhola et al., 2022). Further, teams need to agree on the analysis and implications of results and the implementation of findings. The processes include stages of 'learning, experimentation, reflexivity, and monitoring by depending on continuous feedback loops from the environment and between different organizational levels' (Strand et al., 2022).

This paper contributes to understanding of transdisciplinary research by exploring how these challenges can be usefully conceptualized as tensions between opposing pressures. By examining tensions, the paper explores how transdisciplinary team members cope with being pulled in different directions as they navigate through the tensions and paradoxical positions arising when aiming to meet multiple objectives. Through a scoping review of the literature, this paper addresses the research question: How are the tensions between scientists and non-scientists managed at different stages of a transdisciplinary research project?

We define transdisciplinary research as research conducted with actors from different sectoral and disciplinary backgrounds to work together on a common mission. We analyze the process of transdisciplinary research through the lens of institutional logics (Thornton et al., 2012), exploring the values and motivations of collaborators as they address the tensions of collaborative processes. The paper contributes to theories of knowledge generation for sustainability by showing how tensions in transdisciplinary research lead to particular challenges that can be overcome if individuals within projects have the competencies to navigate their way through complex relationships. By drawing on the theories of institutional logics, we are able to identify specific challenges for building competencies.

Much writing on transdisciplinary research related to sustainability has been normative, presenting the arguments for this alternative approach to research (Thorén & Breian, 2016). We go further and explore the capabilities for managing transdisciplinary activity and the tensions between the different actors involved. This sheds light on the black box of the transdisciplinary process. The theoretical lens of institutional logics helps identify perspectives, drivers, goals and institutional limitations of collaboration so we can then identify how to develop more effective transdisciplinary projects to address the challenges of sustainability development. We do this by answering the research question: How do those involved in transdisciplinary research navigate the tensions between different perspectives and goals?

The paper starts by exploring the transdisciplinary turn in sustainability-related science before introducing the concept of institutional logics and the methods used. Through a scoping review of the literature, we analyze the different challenges at different stages of transdisciplinary sustainability research projects. We particularly focus on the process of combining logics and the strategies used to navigate between competing logics. We conclude by outlining an agenda for facilitating the success of future multi-actor transdisciplinary initiatives.

2. The transdisciplinary turn?

Transdisciplinary research approaches draw on a range of paradigms and emerging processes shaping the generation of knowledge and the concern with sustainability (Hirsch Hadorn et al., 2006; Klein, 2015). At the same time, there was a drive for academic research to demonstrate value for money and the translation of research into practical outcomes. Transdisciplinarity therefore draws on ideas of co-production (Jasanoff, 2004; Lemos & Morehouse, 2005) and the generation of knowledge from a range of stakeholders, what some term Mode 2 knowledge (Gibbons et al., 2004; Thorén & Breian, 2016). Rather than prioritizing the role of academia in knowledge production processes, such approaches envision a wider range of actors collaborating together, thus offering alternatives beyond the traditional perspective of the nature of science. Transdisciplinary research is therefore conceptualized in contrast to academic disciplinary focused research that fits within the boundaries of research that are used to delineate subject areas, university departments, research associations, and journals.

There are rising numbers of transdisciplinary research projects where academics from a range of fields engage in collaborative research in teams that include representatives from other sectors and from businesses, civil society, the state and other citizens (Klein, 2015). Transdisciplinary research and systems thinking approaches are needed in which basic and applied research are combined to generate effective actionable, solution-oriented knowledge to inform and guide decisions by policy makers and practitioners at all levels of governance (Future Earth, 2021). These transdisciplinary approaches are a more deliberative form of science that pays attention to the complexity of working across multiple disciplinary perspectives and scales, as well as moving across the divides between academic science and professional knowledge. Further, literature on sustainability science indicates that transdisciplinary approaches are seen as the best way to tackle interconnected issues (Clark, 2007; Clark et al., 2016; Scholz & Steiner, 2015a; Siew et al., 2016).

The different actors involved in collaborative research can come from different professional as well as disciplinary backgrounds (Harris & Lyon, 2013; Siew et al., 2016). As the impact of science on society has grown, a deliberative turn has encouraged engagement of the public with debates about science, priorities and setting agendas (Hegger et al., 2012; Wilsdon, Wynne & Stilgoe, 2005). Much research in innovation studies has focused on business-academia relationships (Katz & Martin, 1997) with further research also emphasizing the role of other professions such as civil society (Geels, 2014) and professional practice experts (Enengel et al., 2012).

Within professions there are common cultures, values, methods, and expectations (Harris & Lyon, 2013; Pohl et al., 2010). These shape the reward systems and conceptual approaches (Thornton et al., 2012). They come together from different sectors and disciplines in what we call the transdisciplinary space (see Figure 1). It is this black box of transdisciplinarity (Thorén & Breian, 2016) that requires further explanation and theorization. This transdisciplinary space can be a space where limitations from scientific knowledge can be overcome (Barry et al., 2008). The processes to conduct transdisciplinary work allow for different types of knowledge to be given equal weight in the project development and execution (Shackleton et al., 2023). Fundamental to this is the recognition of lay and experiential knowledge, arising from commercial, practice-based, or personal experience and empowerment, where practitioners are given

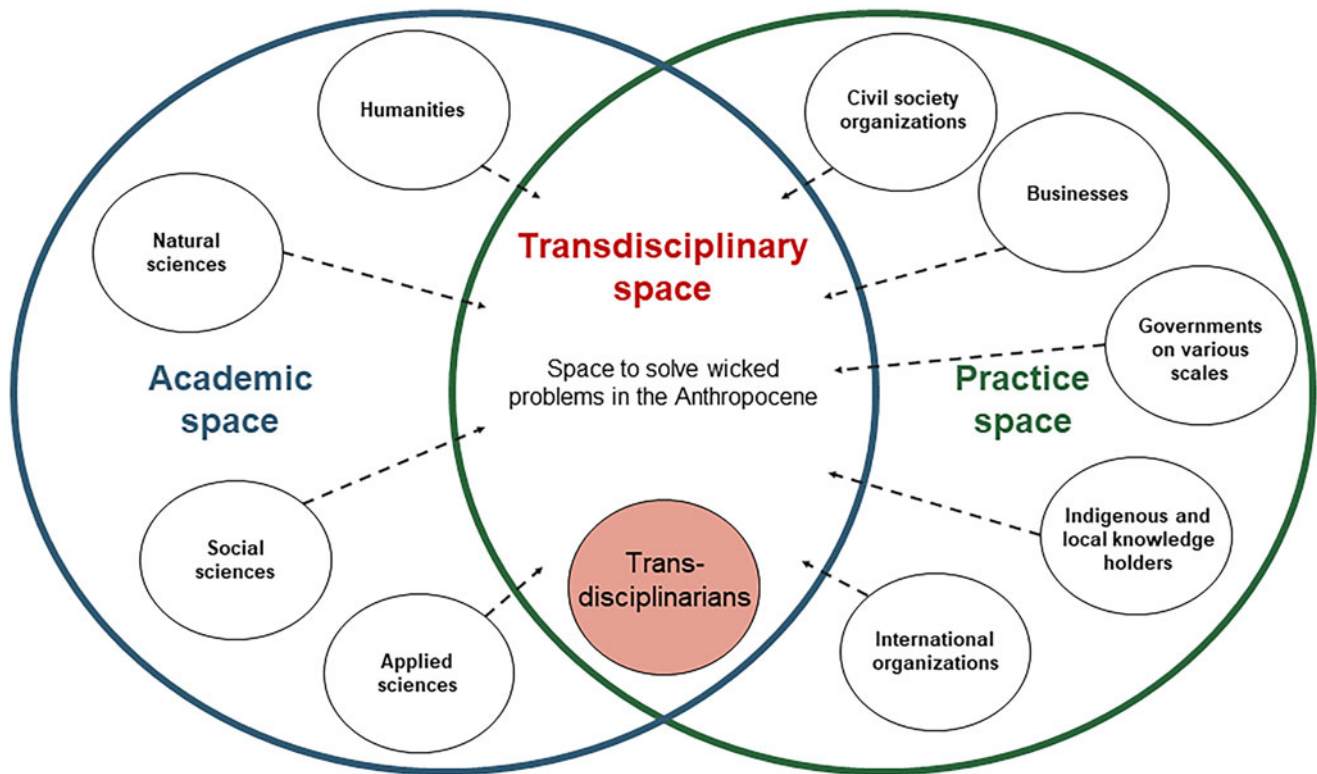


Figure 1. Indication of the transdisciplinary space where transdisciplinarians navigate institutional tensions to solve wicked problems in the Anthropocene. The Figure contains a selection of actors for illustration purposes. Each actor can make contributions or move into the transdisciplinary space, as indicated by the dashed arrows. We recognize that within each group of actors there is much diversity to be considered.

authority to implement findings (Brandt et al., 2013). Where relevant, knowledge from different types of knowledge holders, also referred to as knowledge that is ‘otherwise’ (Rinaldi, 2023), and systems such as those from indigenous communities can also be specifically considered to further impact (Strand et al., 2022). Participative approaches can vary in their level of engagement, interaction, and power sharing between researchers and the participants (Arnstein, 1969).

Thus, the drive towards transdisciplinary research also comes from governments and funding agencies, seeking to ensure that research has impact, that is, is relevant and salient to real world challenges, and makes a difference to lives, livelihoods, and society. This has resulted in a growing body of research programs and a requirement of some funders for research programs to have an element of transdisciplinary research (examples include: the Belmont Forum, the European Union’s 7th Framework Programme (FP7), US National Science Foundation funded Engineering Research Centers). Others have been highlighted in academic literature (see Jahn et al., 2022; Mertens et al., 2022) and research programs focused on global challenges (Lieberknecht et al., 2022) and ‘knowledge exchange’ (Lyll et al., 2015; Phillipson et al., 2012). In the case of the Belmont Forum, impact is ensured by a minimum of at least one end-user for every stage of the project who is in a position to implement changes in society. In a study of ten transdisciplinary agri-environment research projects, more than six cited criteria from funders as shaping the move to a transdisciplinary approach (Harris et al., 2009).

Outputs from these research programs include papers reflecting on the transdisciplinary research process itself (see examples Table 1). This growing literature seeks to learn from

transdisciplinary research processes, to identify ‘best practices’, lessons learned, and ways forward. As transdisciplinary research projects have varied goals, academic expertise, and participating collaborators, it is not realistic to aim for a single ‘approach’ or method (e.g. Benham & Daniell, 2016; Butt & Dimitrijević, 2023; Howarth & Monasterolo, 2016; Price et al., 2023; Rinaldi, 2023; Scholz & Steiner, 2015a; Tschakert et al., 2016; Van der Hel, 2016).

A fundamental challenge within transdisciplinary research is finding ways of guiding the diverse perspectives towards a common goal. While the vision or goal of the project may be common, identifying the best routes and methods to achieve it are more challenging when combining fundamentally different epistemologies, ontologies, and cultures of the varying participants. Toomey et al. (2017) consider not only research impact, but also the quality of the research implementation space, considering values, ethics, attributes, and institutional and personal dynamics within transdisciplinary projects.

We reject the notion of a single transdisciplinary method, but rather identify key factors at each stage of the research process. We offer the lens of institutional logics, recognizing the differing practices and values of each participant (Scholz & Steiner, 2015b), the different tensions found in transdisciplinary research, and the way transdisciplinary researchers can learn to navigate through such challenges.

3. Institutional logics and transdisciplinary research

We argue that there is a need for an analytical framework that contributes to understanding tensions in transdisciplinary research deriving from the different values and motivations of

actors as they come together from different professions, traditions, and cultures. We therefore explore the different institutional logics shaping individual and organizational action. Institutional logics can be defined as ‘socially constructed, historical patterns of cultural symbols and material practices, including assumptions, values and beliefs, by which individuals and organisations provide meaning to daily activity, organize time and space, reproduce lives and experiences’ (Thornton *et al.*, 2012). They can be experienced as sets of organizing principles, practices and objectives that influence individual behavior.

Transdisciplinary research involves bringing together people shaped by different situations and institutional logics (Swan *et al.*, 2010). Of particular importance are the logics of different professions, but there are also the logics of markets, the logics of the public sector (DiMaggio & Powell, 1983), and the logics of corporations (businesses, universities, NGOs). For example the sphere of the market shapes how employees of businesses may be driven by the profit motive, but this is tempered by professions with concerns for reputation, relationships, and the quality of their craft (Thornton *et al.*, 2012). Within academia, the dominant logic is around knowledge generation through applying scientific approaches with established methods to collect and analyze information, particular motivations around publishing in journals ranked according to particular criteria (Felt *et al.*, 2012), conceptions of rigor that also shape the length of time needed for research, as well as non-codified sets of values such as particular writing and communication styles (Bartunek & Rynes, 2014). These logics set academics apart from other non-academics involved in transdisciplinary research resulting in potential tensions. Such cultural differences and tensions between players can lead to disincentives to work across professional boundaries (Hicks & Katz, 1996). In transdisciplinary research, the different actors and individuals find ways of bringing different logics together in ways that help them navigate the tensions. An understanding of the process of transdisciplinary research requires an exploration of these different logics and how they interplay.

4. Method

We conducted a scoping review of peer-reviewed literature concerning the process of collaboration in transdisciplinary research projects. The review drew on literature identified using Scopus. Scopus was selected among different databases, given its broad coverage of quality peer-reviewed literature relevant to the theme of environmental management and sustainability science. The search terms ‘transdisciplinary’ or ‘transdisciplinarity’ were used to identify documents with relevant terms in the title and keywords, published between January 1979 and June 2023 in peer reviewed English language journals. The resulting list of 582 manuscripts was divided among the two leading authors for a deductive screening. The purpose of the screening was to remove duplicates, and to remove papers not relating to the theme using the title, keywords, and reading through the abstracts. We paid particular attention to manuscripts that reviewed transdisciplinary programs or analyzed the process of transdisciplinary research collaboration from the perspective of practitioners and academic researchers. The lead author checked for consistency in the screening process and went through all the titles, keywords, and abstracts to confirm suitability of the manuscripts for the study. This resulted in 221 papers focused on transdisciplinary research practice related to the theme of environment and sustainability science, which were read in depth.

We analyzed the literature through a two stage process of coding. As a first stage, we coded material using the common categorization of the innovation/research process to provide a structural framework drawn from the reviews of research programs and specific transdisciplinary projects reported in the literature. This starts with problem identification, before moving to building teams, setting methods and data collection, analyzing results, and sharing findings. A second more inductive stage of coding identified sub-categories of tensions and approaches to navigate them which were emerging in the literature. This framework for analysis allowed us to identify and differentiate the challenges and tensions at each stage of the research process. We categorized the tensions and approaches within the framework as they have been described in the manuscripts. This gave us an overview of the state-of-the art and the framework allowed us to identify and differentiate the challenges and tensions at each stage of the research process. We documented this structure in Table 1 and derived key overarching messages with a focus on indicating tensions between institutional logics and learning how to navigate these tensions. While this was useful for reviewing the growing literature base and identifying the different contexts for exploring the tensions between logics, we want to highlight that this is a simplification of a messier reality of research practices with overlapping stages and feedback from one stage impacting on others (Lang *et al.*, 2012).

This framework was then analyzed through the lens of institutional logics, focusing on how institutional logics and perspectives can shape the debates and discussions within transdisciplinary research. Finally, our analysis informed a discussion on the development of a research and practice agenda for how to move forward in dealing with tensions and building capabilities for a future of transdisciplinary research that can tackle the wicked problems of the Anthropocene.

5. Navigating the tensions in transdisciplinary research

Through identifying how to manage and navigate the different tensions, the projects reported in the literature built the capacity of team members and provided valuable insights into capability building of transdisciplinary researchers. Each set of actors have their own multiple logics (values, assumptions and practices) derived from the logics of their professional or disciplinary backgrounds coupled with the multiple logics of the project and their individual beliefs and value systems. They may have a dominant logic (e.g. knowledge generation for academia, social/environmental impact and public benefit for civil society and financial objectives for business) and also share other logics to varying degrees. Our analysis identified these different logics as they are reported at different stages of the innovation and research process.

Table 1 summarizes our analysis of the literature on the process of transdisciplinary research focusing on sustainability, and sets out a framework for understanding how transdisciplinary projects can overcome the tensions between logics at different stages of the research process. The table sets out the tensions reported by practitioners and academics at each stage, and the ways that projects reported overcoming the tensions and making transdisciplinary work. We include indicative literature here but recognize that there could be many more references included for each point raised.

5.1 Problem identification and framing

Often transdisciplinary research projects found that those involved may each have different logics and values that shape

Table 1. Learning to navigate tensions in different stages of transdisciplinary research projects

Stages in the research process	Tensions within transdisciplinary team between logics	Approaches to navigating tensions between logics	Indicative references
Problem identification and framing	Different perceptions of problem by different professions (practice/policy/academic) and different disciplines	Adopting holistic approaches that encompass a wider perspective and acknowledge multiple viewpoints	Attwater et al. (2005), Alvargonzalez (2011), Belsky (2002), Binder et al. (2015), Butt and Dimitrijević (2023), Hegger et al. (2012), Lieberknecht et al. (2022), Nicolescu (2002), Scharff and Stone (2022)
Building the transdisciplinary research team	Selecting collaborators with academic research experience or with business/policy/civil society practical experience	Communication avoiding disciplinary and profession specific jargon Build teams that have existing relationships and experience of working together. Allow time for new relationships to be built. Facilitators to support collaboration and ensure all voices heard, including use of ‘boundary spanners’	Bracken and Oughton (2006), Bruce et al. (2004), Cundill et al. (2015), Harris et al. (2009), Holzer et al. (2019), Jones and MacDonald (2007), Lieberknecht et al. (2022), Mauz et al. (2012), Pohl (2005), Radinger-Peer et al. (2022), Renner et al. (2013), Schauppenlehner-Kloyber and Penker (2015), Taylor et al. (2021), Thomas et al. (2018), Yusuf (2008)
Setting the methods and managing data collection	Experiential or experimental data; qualitative or quantitative data; sample frames (size and location) Researcher led or practitioner/citizen reporting	Recognize the different forms of knowledge Communication and flexibility allows negotiation over different types of data; Transcend disciplinary boundaries and leave behind the straight jacket of disciplines	Giri (2002), Horlick-Jones and Sime (2004), Knapp et al. (2019), Radinger-Peer et al. (2021), Raymond et al. (2010), Scharff and Stone (2022), Shrivastava et al. (2013), Siebenhüner (2018), Thomas et al. (2018)
Analyzing and integrating results	Isolating variables or examining holistic interaction of multiple variables in practice	Synthesis of different sources of data Anticipate need to interpret data from multiple scales as research is formulated	Eigi-Watkin and Koskinen (2023), Hölsgens et al. (2023), Huber and Rigling (2014), Lacy et al. (2013)
Dissemination, publishing and implementing results	Accessibility of results: protecting sensitive / commercial information (intellectual property or negative results) vs communication and dissemination in public sphere Different concepts of quality of data Quick implementation or waiting for full results/publication	Recognize need for timely non-academic outcomes for business and civil society Ensure results are widely understandable Recognition that quality may be defined by salience to practitioners and legitimacy for wider society as well as credibility for the scientific community Ensure all partners are engaged through to implementation	Brandt et al. (2013), Boon et al. (2014), Brandt et al. (2013), Eigi-Watkin and Koskinen (2023), Guggenheim (2006), Harris and Lyon (2013), Hölsgens et al. (2023), Houser et al. (2021), Holzer et al. (2019), Kok et al. (2021), Lux et al. (2019), Polk (2015), Schmidt and Pröpper (2017)
Evaluating the research practice	Allocating time and resources for reflecting about the process	Establish systems of co-reflection and learning from the start, preferably face-to-face Allow time and space for co-reflection Develop adaptive strategies and be flexible Feed into design of future projects and funding programs	Gaziulusoy et al. (2016), Holzer et al. (2018), Luks and Siebenhüner (2007), Plummer et al. (2022), Podesta et al. (2013), Radinger-Peer et al. (2022), Roux et al. (2010), Scholz and Steiner (2015b)

their perceptions of a research problem or ways of framing it, which can result in the need to address conflict among team members (Dewulf et al., 2007; Hegger et al., 2012). This conflict comes from different personal and organizational goals. Pohl (2005) distinguishes between pure intellectual research and problem driven and action oriented research. Academics with their dominant logic of knowledge generation through scientific methods may see collaboration as a route to the production of new knowledge, whereas practitioners may see the collaboration as an approach to steer research towards the implementation of solutions to real world problems (Polk, 2015).

Transdisciplinary research can encompass many forms of knowledge including practice based and experiential knowledge alongside academic/scientific knowledge that may be quantitative, qualitative, large scale, micro scale, or case studies (Lyon, 1996; Raymond et al., 2010; Shrivastava et al., 2013). Further, transdisciplinary research can engage with other sectors in ways that allows for the generation of new knowledge and mutual learning, resulting in impacts beyond academic advancements (Strand et al., 2022). Transdisciplinary research challenges academic protectionism (Nicolescu, 2002) and can result in conflictual relationships between different professions or disciplines.

Analysis and reflections on transdisciplinary projects in practice identify ways of managing the tensions between logics (Brink et al., 2018). Non-reductionist and holistic approaches include multiple theoretical approaches and attention to the dynamics of whole systems (Alvargonzalez, 2011; Attwater et al., 2005). Such holistic approaches are found in research on sustainability science, sustainable livelihoods and community conservation where boundaries between disciplines and approaches are blurred (Belsky, 2002).

5.2 Building the transdisciplinary research team

A paradox inherent in transdisciplinary research is that its strength lies in gathering a diverse group of perspectives and players, but they must then be aligned towards common goals and research outcomes, with some authors calling for 'convergence on univocal statements' (Boon et al., 2014, p. 64). While diversity within teams can stimulate creation of new knowledge, too much diversity brings new challenges impacting communication and mutual understanding within the team, and may result in transdisciplinary team members being on different 'wavelengths' (Boon et al., 2014). Higher cognitive dissonance (i.e. from a broader range of backgrounds) offers more opportunities for generation of new knowledge and transdisciplinary learning (Boon et al., 2014; Nooteboom, 1999) but also greater tensions.

Analyses of transdisciplinary projects report that few concepts are self-evident to all members of the research team, and differing concepts and meanings are not neutral (Bruce et al., 2004). Communication among team members is a crucial aspect to facilitate collaboration and navigate the tensions between logics, avoiding the boundaries created by profession specific or disciplinary jargon that inhibits mutual understanding (Binder et al., 2015; Bracken & Oughton, 2006; Broto et al., 2009; Hackett, 2005; Harris et al., 2009; Mauz et al., 2012; Price et al., 2023). Communication issues are even greater when international projects have to cope with language barriers (Siew et al., 2016).

Building relationships to encourage deeper connection among participants is important, although this can take time and resources (Bracken & Oughton, 2006; Jones & MacDonald, 2007). Some argue that inherently this means transdisciplinary

projects cannot be achieved in one or even three years and thus require long-term commitment and funding (Lieberknecht et al., 2022). As individual participating organizations change and develop, representatives attending meetings may change over the course of the project, creating greater challenges in terms of building personal relationships (Harris et al., 2009). Long term amicable relations engender openness and trust, allowing research teams to raise questions and challenge ideas in a mutually constructive way (Harris & Lyon, 2013). Strong ties between members of research teams result in exchange of more 'fine-grained' information and hence more intensive collaboration (Boon et al., 2014, p. 54).

Facilitators are important in building relationships between actors and ensuring that all voices are encouraged to speak out and be heard (Renner et al., 2013; Taylor et al., 2021). Where the cultural distance between parties is great, these intermediaries can bridge the boundaries by recognizing and working with the competing logics (Schauppenlehner-Kloyber & Penker, 2015; Yusuf, 2008). This allows 'boundary spanners' (Williams, 2002) to bring diverse institutional logics and cultures from practice and academia together. They can support communication (Horlick-Jones & Sime, 2004), and some projects have engaged 'embedded researchers' with the specific goal of bridging between practice and academia (Taylor et al., 2021). Similarly, boundary organizations are designed to mediate between different communities and build links between intellectual neighbors (Cundill et al., 2015).

5.3 Agreeing the methods and managing data collection

As transdisciplinary research teams bring together people with widely differing institutional logics and approaches to the concept of knowledge, challenges arise concerning the selection of methods for investigating problems. These challenges relate to the nature of knowledge (or epistemology) as well as the approaches to collecting evidence. Theoretical and methodological pluralism challenges the concept of a single view of quality as defined against disciplinary standards (Guggenheim, 2006). There can be tensions with opposing views concerning the type of data (qualitative or quantitative data), sample frames (size and location), and the means of collection (practitioner or researcher led). Furthermore, there can be differences between practitioners and academia in terms of the rigor required behind particular evidence (Harris et al., 2009). Where problem identification and framing calls for a holistic approach that allows for the exploration of the interaction of variables, there are challenges for researchers looking to isolate particular variables and identify causality. Academic researchers may be looking for evidence to satisfy a peer review process whereas business and civil society organizations may want to know what works in a particular location (Houser et al., 2021). This raises particular challenges with regard to the nature of 'proof' that affects how a transdisciplinary research project designs data collection and how it shares any results. While transdisciplinary research can be challenging for some, others find a sense of freedom as they abandon constraints and move to new disciplines (Giri, 2002; Houser et al., 2021) so transcending boundaries and avoiding the 'institutional and conceptual straight-jacket of the disciplines' (Horlick-Jones & Sime, 2004, p. 453).

5.4 Analyzing and integrating results

With multiple sources of data from different actors each shaped by different institutional logics, there are tensions within a

transdisciplinary project between holistic approaches that examine a wide range of variables and reductionist approaches that seek to isolate variables. Reflections on managing transdisciplinary research projects show the importance of finding ways of synthesizing such material and examining the interconnections of ecological processes (Huber & Rigling, 2014). What distinguishes inter and transdisciplinary studies from multidisciplinary studies is that synthesizing and interpreting complex data from multiple scales and disciplines happens as research is formulated and undertaken, rather than as an afterthought (Lacy et al., 2013). The more challenging component for transdisciplinary research is translating results from one case to another, and building strong arguments by analogy for this are key (Eigi-Watkin & Koskinen, 2023). Working across sectors can also mean continuity of a project beyond the conventional period that research is funded, with some actors being better positioned to continue implementation (Hölsgens et al., 2023).

5.5 Publishing, dissemination, and implementing results

The different goals and institutional logics of business, civil society, policy makers and academics require careful management of the project outputs (Boon et al., 2014). Some team members may prioritize academic publications, while others may desire outputs which are more relevant to public goals (Boon et al., 2014). Other stakeholders, including NGOs, may want outputs more relevant to their own organizations (Harris & Lyon, 2013). Buizer et al. (2016) identify the challenges of co-authoring outputs with government departments that may require approval, or with communities, for whom publication may not be a priority. Furthermore, academics are driven by the institutional logics of universities demanding publications that 'score' highly for research assessment, and are not as richly rewarded for other types of outputs (Schmidt & Pröpper, 2017). Some researchers note that academics feel a project is finished when academic research is completed and published, whereas practitioners feel the project is not complete until findings are implemented into practice and evaluated (Harris & Lyon, 2013). Successful collaborations that overcome tensions were found to consider the needs of different audiences of the research. Outputs need to be relevant to all the stakeholders involved (Bracken et al., 2015).

Transdisciplinarity as a research approach is supported by practices that use the simplest language possible and produce results that are widely understandable (Brandt et al., 2013). Quality is therefore not only judged on traditional academic conceptions of research rigor, but also by the salience to citizens, civil society, and businesses involved (Boon, et al., 2014; Brandt et al., 2013; Guggenheim, 2006).

5.6 Evaluating the research practice

Evaluating transdisciplinary projects cannot be done with a single framework for all projects. Each project works with multiple perspectives, knowledge systems, and types of evidence, which requires an adjusted co-learning performance assessment and impact evaluation framework (Plummer et al., 2022). Transdisciplinary projects described in the literature frequently report an element of reflection within the project (Bracken & Oughton, 2006; Fry, 2001; Jones & Macdonald, 2007; Plummer et al., 2022; Podesta et al., 2013; Pohl, 2008; Romero-Lankao et al., 2013; Roux et al., 2010) that, if done early in the project, can feed into improvements of project design throughout the process (Podesta et al., 2013; Roux et al., 2010).

Managing transdisciplinary projects can be complex, with each partner having different expectations (Plummer et al., 2022); therefore allowing time and space for 'room to fail' and the opportunity to learn from mistakes is needed. If challenges emerge during the research process (Gaziulusoy et al., 2016), commissioners of transdisciplinary research may be asked to recognize the potential uncertainties (Simon & Schiemer, 2015) and be flexible with research plans. Successful collaboration occurs when there is time for co-reflection and social learning, and needs to be written into the project (Hegger et al., 2012; Plummer et al., 2022; Radinger-Peer et al., 2022). However, funders want a clear plan and budget for a project, whereas transdisciplinary projects often involve negotiation along the way, which means that proposals contain an element of uncertainty that is hard to plan for and cost in proposals. Face to face meetings and communication are reported to be better than written reports for exploring differences and fostering social learning (Bruce et al., 2004; Crowston et al., 2015; Guimarães et al., 2015; Renner et al., 2013). Experiences throughout the COVID-19 pandemic era also underlined that online meetings were challenging for transdisciplinary work (highlighted in the Sustainability, Research and Innovation 2023 Congress session titled: Just transition and climate change resilience in coastal communities). Furthering the evaluation of research practices, going beyond journal publications and impact factors will require new types of impact assessments such as interviews or surveys in society and uptake in policy (Beyond the Academy, 2022). Participatory Impact Pathways Analysis (PIPA) approach is one other way for measuring impact (Radinger-Peer et al., 2022). At a wider scale, there is a need to evaluate transdisciplinarity at a funding program level (Holzer et al., 2018) to ensure learning from individual projects is fed into future programs.

6. Managing tensions arising within transdisciplinary processes: A research and practice agenda

Having identified the tensions arising within transdisciplinary research teams at each stage of the research process, and approaches to navigate those tensions, this paper now sets out an agenda for further consideration in future research on transdisciplinary efforts.

6.1 Accepting ambiguity

Overcoming or working with tensions requires individuals and organizations with the capacity to accept and be open to a diversity of perspectives, and hold multiple logics at one time in what has been referred to as ambidexterity and managing paradox (Andriopoulos & Lewis, 2009; Besharov & Smith, 2014). Managing transdisciplinary research entails finding ways of working with the multiple logics that may be in conflict and managing the tensions that may arise. Within the transdisciplinary space, the clashes of logics co-exist with collaborative working. Some may view this space as a zone of trade-offs where benefits are perceived to outweigh the challenges of collaboration. However, in some instances this space becomes a 'sweet spot' where, released from the 'straight jackets' of disciplines and institutional logics, groups are able to tackle challenges in new and innovative ways to investigate complex systems and co-produce new knowledge and insights into sustainability. Shared vision among all partners of the project is at the heart of building trust and working for a goal that is bigger than the sum of the parts.

6.2 Supporting meaningful collaboration: moving from diversity to inclusion

While much research has reflected on the transdisciplinary process from the perspective of academia, there is less research that presents the voice of other participants (Bracken *et al.*, 2015; Maynard, 2013 and Lane *et al.*, 2011). It is these actors, drawn from business, civil society, policy makers, the wider public, and other knowledge holders whose contributions make interdisciplinary research transdisciplinary (See Figure 1). Research with these stakeholders would inform wider debates about the benefits, pitfalls, and future directions of transdisciplinary research. Research is also needed to explore the best approaches for building capacity of boundary spanners, partners in think tanks, public sector and businesses such as consultancies, as well as universities.

6.3 Fostering relationships

Relationships and trust (Fry, 2001; Harris & Lyon, 2013) are at the heart of transdisciplinary research with real challenges in terms of shared understanding and communication when cognitive distance and major epistemological and ontological differences exist across the research team and contrasting institutional logics. The experience of projects reported in the literature highlights the importance of compromise, flexibility and negotiation (Horlick-Jones & Sime, 2004), as well as creating bridges where there is distance (Harris & Lyon, 2013; Reed & Abernethy, 2018; Yusuf, 2008). Competencies of trust building are thus identified to be important.

6.4 Acknowledging and managing power within collaborative teams

Relationships are shaped by power relations (Cundill *et al.*, 2015; Kareem *et al.*, 2022; Schmidt & Pröpper, 2017; Simon & Schiemer, 2015). An analysis from 59 transdisciplinary projects in Germany by Jahn *et al.* (2022) found this to be an important challenge. Power shapes both who is involved, as well as how they are involved. Those who control funding are also able to exert power (Schmidt & Pröpper, 2017), sometimes through sub-contracts to partners, or even peer pressure (Harris & Lyon, 2014). If there are considerable imbalances of power, participation may be tokenistic, and some stakeholders not represented at all (Botha *et al.*, 2014; Renner *et al.*, 2013).

Research funding exerts the most explicit form of power within projects. The source of funding (academic research councils, government bodies or non-academic sources) often dictates who is eligible to apply (or at least lead a bid), as well as the nature of the goals and outputs. Research councils generally require academic institutions to play a lead, in which case they become gatekeepers to funding. So this influences projects from the initial call and formation of the project team. Funding programs identify research priorities, eligibility of research partners, types of activity or role (e.g. postdoc, PhD) which may be funded, and any co-funding requirements. These can impact on research priorities and research team membership, and potentially shape proposed outputs from the project, so impacting right through the project to when final outputs are prepared and disseminated. Project proposals require a particular academic style and language which may be more accessible to some partners than others.

A variety of methods have been used to tackle imbalances of power, such as stakeholder workshops, face-to-face team meetings, data collection methods, reporting, and knowledge exchange

with the many audiences for transdisciplinary research (public, practitioners, industry, media, academic). The relative costs of using such methods to address power imbalances should be acknowledged.

Imbalances of power within projects are often noticed when projects reach the stage of sharing outputs. Different stakeholders may desire different outputs, with some desiring academic publications, others wanting outputs more suited to public goals (Boon *et al.*, 2014) and others (e.g. NGOs and other stakeholders) wanting outputs suitable for distribution by their own organizations (Harris & Lyon, 2013). Jahn *et al.* (2022) encourages 'research to increase efforts to mitigate the tradeoffs between societal and academic impacts and outputs'.

6.5 Building capabilities for a future of transdisciplinary research

Transdisciplinary require the specific skills and competencies to enable them to engage with the multiple logics found in such projects (academic knowledge generation, commerce, policy change etc). We argue that there is a clear role for transdisciplinary research but more attention has to be given to building capabilities of all those involved (in academia, business, civil society, public sector). This can include learning through experience on projects but also requires higher education to train the transdisciplinary of the future.

As demand for transdisciplinary research increases there is growing interest in what makes a good transdisciplinary researcher. Research on the competencies of what make good transdisciplinary are still limited (Trencher *et al.*, 2014; Wiek *et al.*, 2011). In particular, what 'softer skills', qualities, or characteristics a researcher needs to enable them to work within the tensions of transdisciplinary research (Schönenberg *et al.*, 2017). Jay (2013) described the key competencies of individuals and teams in such boundary spanning spaces is the ability to find ways of working together and navigating the different tensions to foster synergistic relationships rather than perpetuating situations of clashing cultures. This competency can be seen at all stages of the research process from problem identification and defining the goals of the project, through the research process, to delivering outputs.

Transdisciplinary research is seen as an academic borderland with academics uncertain whether it is an 'in-between space' or a 'cross-cutting' space (Felt *et al.*, 2012; Lau & Pasquini, 2004). Some may feel a transdisciplinary is an excluded non-entity who does not fit into the structure and systems of academia, whereas others see transdisciplinary as a new form of researcher. It requires a particular set of skills to act as a transdisciplinary, and there are further challenges to working across the boundaries of research and practice, and at the interface of science – policy. This therefore raises questions regarding the types of training and education required to cope with the challenges and tensions discussed in the previous sections. Central to this debate is the mono-disciplinary focus of academia.

Max-Neef (2005) called for a reorientation in higher education to support transdisciplinarity to occur within an individual's thinking processes. Increasingly, transdisciplinary masters and doctoral programs are offered that seek to foster an ethos of engagement among disciplines and beyond academia from the outset of academic careers (Felt *et al.*, 2012). These programs have a role to play in creating alternative academic spaces and a sense of belonging. Such programs seek to foster an ethos of engagement among disciplines and beyond from the outset of

academic careers, recognizing that transdisciplinary communities of practice must be nurtured (Cundill et al., 2015). These programs are considering wider professional development (Cianelli et al., 2014) and bridging skills (Goven et al., 2015). Fam et al. (2016) identify 6 C's of a transdisciplinarian (curiosity, creativity, commitment, critical awareness, communication and connectedness). Team building has been brought forward as an important element for the success of a transdisciplinary project (Radinger-Peer et al., 2022). This 'non-science expertise' (Popa et al., 2015) includes practices of reflexivity and social learning, all skills required to achieve transdisciplinary outcomes of mutual transformational learning (Mitchell et al., 2017). Emerging research acknowledges that these skills, including innate abilities, are part of the characteristic of a transdisciplinarian (Augsberg, 2014; Fam et al., 2016).

6.6 Creating reward structures to support those engaging in transdisciplinary research

Transdisciplinary research presents challenges to PhD and postdoctoral researchers who are seeking permanent posts within universities as academic appointments are largely based on having a track record of publications in high impact journals which are central to specific disciplines (Houser et al., 2021). However, those who seek to move into employment outside of academia have found that the transdisciplinary research experience and the links to practice that were involved have facilitated their transition to new roles (Felt et al., 2012). Thus, there is a debate as to whether training in transdisciplinary research should build the capacity of those seeking to stay within the academic world, or encourage those with experience and understanding of academic research to move toward work in civil society, the public sector, or business.

The requirement to publish in top ranked journals leads to an emphasis on mono-disciplinarity and is formalized by 'Indicator driven assessment policies that foster disciplined mainstream research' (Rafols et al., 2012). Earlier reviews of sustainability science (Brandt et al., 2013) found that papers were generally published in journals with low impact factors (defined by the average citations per paper) although in recent years there is an increasing trend of journals with a sustainability science focus increasing their impact factors.

Transdisciplinarity can create alternative norms, implicit values, and institutions (funding arrangements, publication outlets, conferences, and network) (Felt et al., 2012). However, such an alternative space can impact on the traditional models of career progression (Duberley et al., 2006; Harris et al., 2009).

7. Conclusions

This paper sought to explore the tensions in transdisciplinary approaches at different stages of research and innovation projects. We also reviewed the skills, knowledge and attributes required of transdisciplinary researchers to navigate the tensions. This work will support the development of a cadre of researchers able to work effectively to address the wicked problems of global sustainability in the Anthropocene using transdisciplinary approaches.

Through our review we found that transdisciplinary research is perceived to be more challenging than traditional research, due to the wider breadth of knowledge required, and the time required to get to know fellow team members and develop relationships and negotiate projects. In this paper we argue that learning to work with the different logics and values of all members of the project

team is fundamental. Negotiation is required to address power imbalances between disciplines, and between scientists and lay practitioners. While this can require trade-offs, transdisciplinary research can also lead to new forms of innovation that meet multiple goals (e.g. both knowledge generation, community benefits, and financial profit).

Academic researchers may also have concerns about maintaining the quality of research while compromising with multiple research partners, and the potential impact this may have on academic publications and subsequent promotion within academic institutions. While some feel high levels of personal satisfaction and find the process of transdisciplinary research rewarding and stimulating, others find negotiation and perceived trade-offs off-putting, and return to their disciplinary bases (Guggenheim, 2006).

We believe there is a need for continued learning in transdisciplinary research and our scoping review highlighted the value of documenting lessons learned in peer-reviewed literature to advance the learning curve across organizations. In doing so, we also advance transformations to environmentally safe and socially just societies.

Acknowledgements. This paper draws on and develops an earlier working paper prepared for the ESRC Nexus Network (Harris & Lyon, 2014). The authors would like to acknowledge the Future Earth Health Knowledge-Action Network for the space it provided to discuss the development of this manuscript.

Authors' contributions. FH and FL designed and initiated the project. FH, FL, GS, and KE conducted the review and wrote subsections. FH and FL wrote the first concise draft and GS and KE contributed to the further development. All authors read and approved the final manuscript.

Funding statement. This research was supported by a grant from the UK's ESRC Nexus Network program and ESRC Centre for the Understanding of Sustainable Prosperity.

Competing interests. None.

References

- Alvargonzalez, D. (2011). Multidisciplinarity, interdisciplinarity, transdisciplinarity, and the sciences. *International Studies in the Philosophy of Science*, 25(4), 387–403. <https://doi.org/10.1080/02698595.2011.623366>
- Andriopoulos, C., & Lewis, M. W. (2009). Exploitation-exploration tensions and organizational ambidexterity: Managing paradoxes of innovation. *Organization Science*, 20(4), 699–717. <https://doi.org/10.1287/orsc.1080.0406>
- Arnstein, S. R. A. (1969). Ladder of citizen participation. *Journal of the American Institute of Planners*, 35(4), 216–224. <https://doi.org/10.1080/01944366908977225>
- Attwater, R., Booth, S., & Guthrie, A. (2005). The role of contestable concepts in transdisciplinary management of water in the landscape. *Systems Research and Behavioral Science*, 22(3), 185–192. <https://doi.org/10.1002/sres.668>
- Augsberg, T. (2014). Becoming transdisciplinary: The emergence of the transdisciplinary individual. *World Futures*, 70, 1–14. <https://doi.org/10.1080/02604027.2014.934639>
- Barry, A., Born, G., & Weszkalnys, G. (2008). Logics of interdisciplinarity. *Economy and Society*, 37(1), 20–49. <https://doi.org/10.1080/03085140701760841>
- Bartunek, J. M., & Rynes, S. L. (2014). Academics and practitioners are alike and unlike; the paradoxes of academic-practitioner relationships. *Journal of Management*, 40(5), 1181–1201. <https://doi.org/10.1177/0149206314529160>
- Belsky, J. (2002). Beyond the natural resource and environmental sociology divide: Insights from a transdisciplinary perspective. *Society and Natural Resources*, 15(3), 269–280. <https://doi.org/10.1080/089419202753445106>

- Benham, C. F., & Daniell, K. A. (2016). Putting transdisciplinary research into practice: A participatory approach to understanding change in coastal social-ecological systems. *Ocean and Coastal Management*, 128, 29–39. <https://doi.org/10.1016/j.ocecoaman.2016.04.005>
- Besharov, M., & Smith, W. (2014). Multiple logics in organizations: Explaining their varied nature. *Implications Academy of Management Review*, 39(3), 364–381. <https://doi.org/10.5465/amr.2011.0431>
- Beyond the Academy (2022) <https://beyondtheacademynetwork.org/guidebook/>
- Binder, C. R., Absenger-Helmli, I., & Schilling, T. (2015). The reality of transdisciplinarity: A framework-based self-reflection from science and practice leaders. *Sustainability Science*, 10(4), 545–562. <https://doi.org/10.1007/s11625-015-0328-2>
- Boon, W. P. C., Chappin, M. M. H., & Perenboom, J. (2014). Balancing divergence and convergence in transdisciplinary research teams. *Environmental Science and Policy*, 40, 57–68. <https://doi.org/10.1016/j.envsci.2014.04.005>
- Botha, N., Klerkx, L., Small, B., & Turner, J. A. (2014). Lessons on transdisciplinary research in a co-innovation programme in the New Zealand agricultural sector. *Outlook on Agriculture*, 43, 219–223. <https://doi.org/10.5367/oa.2014.0175>
- Bracken, L. J., Bulkeley, H. A., & Whitman, G. (2015). Transdisciplinary research: Understanding the stakeholder perspective. *Journal of Environmental Planning and Management*, 58(7), 1291–1308. <https://doi.org/10.1080/09640568.2014.921596>
- Bracken, L. J., & Oughton, E. A. (2006). ‘What do you mean?’ The importance of language in developing interdisciplinary research. *Transactions of the Institute of British Geographers*, 31(3), 371–382. <https://doi.org/10.1111/j.1475-5661.2006.00218.x>
- Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D. J., Newig, J., Reinert, F., Abson, D. J., & Von Wehrden, H. (2013). A review of transdisciplinary research in sustainability science. *Ecological Economics*, 92, 1–15. <https://doi.org/10.1016/j.ecolecon.2013.04.008>
- Brink, E., Wamsler, C., Adolfsson, M., Axelsson, M., Beery, T., Bjorn, H., Bramryd, T., Ekelund, N., Palo, T., Sjeldrup, M., Stalhammar, S., & Thiere, G. (2018). On the road to ‘research municipalities’: Analysing transdisciplinarity in municipal ecosystem services and adaptation planning. *Sustainability Science*, 13, 765–784. <https://doi.org/10.1007/s11625-017-0499-0>
- Broto, V. C., Gislason, M., & Ehlers, M. H. (2009). Practising interdisciplinarity in the interplay between disciplines: Experiences of established researchers. *Environmental Science and Policy*, 12, 922–933. <https://doi.org/10.1016/j.envsci.2009.04.005>
- Bruce, A., Lyall, C., Tait, J., & Williams, R. (2004). Interdisciplinary integration in Europe: The case of the fifth framework programme. *Futures*, 36, 457–470. <https://doi.org/10.1016/j.futures.2003.10.003>
- Buizer, M., Arts, B., & Westerink, J. (2016). Landscape governance as policy integration ‘from below’: A case of displaced and contained political conflict in the Netherlands. *Environment and Planning C: Government and Policy*, 34(3), 448–462. <https://doi.org/10.1177/0263774X15614725>
- Butt A.N., & Dimitrijević, B. (2023). Developing and testing a general framework for conducting transdisciplinary research. *Sustainability (Switzerland)* 15(5) art. no. 4596. <https://doi.org/10.3390/su15054596>
- Cianelli, L., Hunsicker, M., Beaudreau, A., Bailey, K., Crowder, L. B., Finley, C., Webb, C., Reynolds, J., Sagmiller, K., Anderies, J. M., Hawthorne, D., Parrish, J., Heppell, S., Conway, F., & Chigbu, P. (2014). Transdisciplinary graduate education in marine resource science and management. *ICES Journal of Marine Science*, 71(5), 1047–1051. <https://doi.org/10.1093/icesjms/fsu067>
- Clark, W. C. (2007). Sustainability science: A room of its own. *PNAS*, 104(6), 1737–1738. <https://doi.org/10.1073/pnas.0611291104>
- Clark, W. C., van Kerkhoff, L., Lebel, L., & Galloin, G. C. (2016). Crafting using knowledge for sustainable development. *PNAS*, 113(17), 4570–4578. <https://doi.org/10.1073/pnas.1601266113>
- Crowston, K., Specht, A., Hoover, C., Chudoba, K. M., & Watson-Manheim, M. B. (2015). Perceived discontinuities and continuities in transdisciplinary scientific working groups. *Science of the Total Environment*, 534, 159–172. <https://doi.org/10.1016/j.scitotenv.2015.04.121>
- Cundill, G., Roux, D. J., & Parker, J. N. (2015). Nurturing communities of practice for transdisciplinary research. *Ecology and Society*, 20(2). <https://doi.org/10.5751/ES-07580-200222>
- Dewulf, A., Francois, G., Pahl-Wostl, C., & Taillieu, T. (2007). A framing approach to cross-disciplinary research collaboration: Experiences from a large-scale research project on adaptive water management. *Ecology and Society*, 12(2). <https://doi.org/10.5751/ES-02142-120214>
- DiMaggio, P. J., & Powell, W. W. (1983). The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields. *American Sociological Review*, 48, 147–160.
- Duberley, J., Cohen, L., & Mallon, M. (2006). Constructing scientific careers: Change, continuity and context. *Organization Studies*, 27, 1131–1151. <https://doi.org/10.1177/0170840606064105>
- Ebi, K. L., Harris, F., Sioen, G. B., Wannous, C., Anyamba, A., Bi, P., Boeckmann, M., Bowen, K., Cissé, G., Dasgupta, P., Dida, G. O., Gasparatos, A., Gatzweiler, F., Javadi, F., Kanbara, S., Kone, B., Maycock, B., Morse, A., Murakami, T., ... Capon, A. (2020). Transdisciplinary research priorities for human and planetary health in the context of the 2030 agenda for sustainable development. *International Journal of Environmental Research and Public Health*, 17(23), 8890. <https://doi.org/10.3390/ijerph17238890>
- Eigi-Watkin, J., & Koskinen, I. (2023). Reasoning by analogy and the transdisciplinary circle: On the problem of knowledge transfer across cases in transdisciplinary research. *Sustainability Science*, 18(3), 1343–1353. <https://doi.org/10.1007/s11625-023-01315-2>
- Enengel, B., Muhar, A., Penker, M., Freyer, B., Drlik, S., & Ritter, F. (2012). Co-production of knowledge in transdisciplinary doctoral theses on landscape development—An analysis of actor roles and knowledge types in different research phases. *Landscape and Urban Planning*, 105, 106–117. <https://doi.org/10.1016/j.landurbplan.2011.12.004>
- Fam, D. M., Smith, T., & Cordell, D. J. (2016). Anatomy of a transdisciplinary researcher: From curiosity to connectedness. In D.M. Fam, J. Palmer, C. Riedy, & C.A. Mitchell (Eds.), *Transdisciplinary research and practice for sustainability outcomes*. Routledge.
- Felt, U., Igelsböck, J., Schikowitz, A., & Völker, T. (2012). Growing into what? The (un-) disciplined socialisation of early stage researchers in transdisciplinary research. *Higher Education*, 65(4), 511–524. <https://doi.org/10.1007/s10734-012-9560-1>
- Fry, G. (2001). Multifunctional landscapes – towards transdisciplinary research. *Landscape and Urban Planning*, 57, 159–168. [https://doi.org/10.1016/S0169-2046\(01\)00201-8](https://doi.org/10.1016/S0169-2046(01)00201-8)
- Future Earth (2021) <https://futureearth.org/wp-content/uploads/2021/04/Future-Earth-Mission-and-Objectives.pdf>
- Gaziulusoy, A. I., Ryan, C., McGrail, S., Chandler, P., & Twomey, P. (2016). Identifying and addressing challenges faced by transdisciplinary research teams in climate change research. *Journal of Cleaner Production*, 123, 55–64. <https://doi.org/10.1016/j.jclepro.2015.08.049>
- Geels, F. W. (2014). Reconceptualising the co-evolution of firms-in-industries and their environments: Developing an inter-disciplinary triple embeddedness framework. *Research Policy*, 43(2), 261–277. <https://doi.org/10.1016/j.respol.2013.10.006>
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., & Trow, M. (2004). *The new production of knowledge: The dynamics of science and research in contemporary societies*. SAGE Publications.
- Giri, A. K. (2002). The calling of a creative transdisciplinarity. *Futures*, 34, 103–115.
- Goven, J., Langer, E. R. L., Baker, V., Ataria, J., & Leckie, A. (2015). A transdisciplinary approach to local waste management in New Zealand: Addressing interrelated challenges through indigenous partnership. *Futures*, 73, 22–36. <https://doi.org/10.1016/j.futures.2015.07.011>
- Guggenheim, M. (2006). Undisciplined research. Structures of transdisciplinary research. *Science and Public Policy*, 33, 411–422. <https://doi.org/10.3152/147154306781778795>
- Guimarães, M. H., McKee, A., Lima, M. L., Vasconcelos, L., Boski, T., & Dentinho, T. (2015). Putting transdisciplinarity into practice: A mixed mode procedure for stakeholder participation in natural resource management. *Journal of Environmental Planning and Management*, 58(10), 1827–1852. <https://doi.org/10.1080/09640568.2014.964850>
- Hackett, E. (2005). Introduction to the special guest-edited issue on scientific collaboration. *Social Studies of Science*, 35, 667–672. <https://doi.org/10.1177/0306312705057569>

- Harris, F., & Lyon, F. (2013). Transdisciplinary environmental research: Building trust across professional cultures. *Environmental Science and Policy*, 31, 109–119. <https://doi.org/10.1016/j.envsci.2013.02.006>
- Harris, F., & Lyon, F. (2014). Transdisciplinary environmental research: a review of approaches to knowledge co-production. ESRC Nexus Network Think Piece Series, Paper 002. http://thenexusnetwork.org/wp-content/uploads/2014/11/Harris-and-Lyon-Transdisciplinary-Research-002_Nexus-Thinkpiece-2014.pdf
- Harris, F., Lyon, F., & Clarke, S. (2009). Doing interdisciplinarity: Motivation and collaboration in research for sustainable agriculture in the UK. *Area*, 41(4), 374–384. <https://doi.org/10.1111/j.1475-4762.2008.00859.x>
- Hegger, D., Lamers, M., Van Zeijl-Rozema, A., & Dieperink, C. (2012). Conceptualising joint knowledge production in regional climate change adaptation projects: Success conditions and levers for action. *Environmental Science and Policy*, 18, 52–65. <https://doi.org/10.1016/j.envsci.2012.01.002>
- Hicks, D. M., & Katz, J. S. (1996). Where is science going? *Science Technology and Human Values*, 21(4), 379–406.
- Hills, J. M., & Maharaj, P. N. (2023). Designing transdisciplinarity for transformative ocean governance. *Frontiers in Marine Science*, 10, 1075759. <https://doi.org/10.3389/fmars.2023.1075759>
- Hirsch Hadorn, G., Bradley, D., Pohl, C., Rist, S., & Wiesmann, U. (2006). Implications of transdisciplinarity for sustainability research. *Ecological Economics*, 60(1), 119–128. <https://doi.org/10.1016/j.ecolecon.2005.12.002>
- Hölgens, R., Wascher, E., Bauer, C., Boll, J., Bund, S., Dankwart-Kammoun, S., Heese, I., Schrot, K., Schultze, J., & Tenambergen, R. (2023). Transdisciplinary research along the logic of empowerment: Perspectives from four urban and regional transformation projects. *Sustainability (Switzerland)*, 15(5), 4599. <https://doi.org/10.3390/su15054599>
- Holzer, J. M., Adamescu, C. M., Cazacu, C., Diaz-Delgado, R., Dick, J., Méndez, P. F., Santamaría, L., & Orenstein, D. E. (2019). Evaluating transdisciplinary science to open research-implementation spaces in European social-ecological systems. *Biological Conservation*, 238, 108228. <https://doi.org/10.1016/j.biocon.2019.108228>
- Holzer, J. M., Carmon, N., & Orenstein, D. E. (2018). A methodology for evaluating transdisciplinary research on coupled socio-ecological systems. *Ecological Indicators*, 85, 808–819. <https://doi.org/10.1016/j.ecolind.2017.10.074>
- Horlick-Jones, T., & Sime, J. (2004). Living on the border: Knowledge, risk and transdisciplinarity. *Futures*, 36(4), 441–456. <https://doi.org/10.1016/j.futures.2003.10.006>
- Houser, M., Sullivan, A., Smiley, T., Muthukrishnan, R., Browning, E. G., Fudickar, A., Title, P., Bertram, J., & Whiteman, M. (2021). What fosters the success of a transdisciplinary environmental research institute? Reflections from an interdisciplinary research cohort. *Elementa*, 9(1), 132. <https://doi.org/10.1525/elementa.2020.00132>
- Howarth, C., & Monasterolo, I. (2016). Understanding barriers to decision making in the UK energy-food-water nexus: The added value of interdisciplinary approaches. *Environmental Science and Policy*, 61, 53–60. <https://doi.org/10.1016/j.envsci.2016.03.014>
- Huber, R., & Rigling, A. (2014). A commitment to continuous research is a key factor in transdisciplinarity: Experiences from the Mounland project. *GAI A*, 23(3), 256–262. <https://doi.org/10.14512/gaia.23.3.10>
- Jackson, T. (2017). *Prosperity without growth: Foundations for the economy of tomorrow*. Routledge.
- Jahn, S., Newig, J., Lang, D. J., Kahle, J., & Bergmann, M. (2022). Demarcating transdisciplinary research in sustainability science – five clusters of research modes based on evidence from 59 research projects. *Sustainable Development*, 30(2), 343–357. <https://doi.org/10.1002/sd.2278>
- Jasanoff, S. E. (Ed.). (2004). *States of knowledge: The co-production of science and social order*. Routledge.
- Jay, J. (2013). Navigating paradox as a mechanism of change and innovation in hybrid organisations. *Academy of Management Journal*, 56(1), 137–159. <https://doi.org/10.5465/amj.2010.0772>
- Jones, P., & Macdonald, N. (2007). Getting it wrong first time: Building an interdisciplinary research relationship. *Area*, 39, 490–498. <https://doi.org/10.1111/j.1475-4762.2007.00767.x>
- Juhola, S., Heikkinen, M., Pietilä, M., Groundstroem, F., & Käyhkö, J. (2022). Connecting climate justice and adaptation planning: An adaptation justice index. *Environmental Science & Policy*, 136, 609–619. <https://doi.org/10.1016/j.envsci.2022.07.024>
- Kareem, B., McClure, A., Walubwa, J., Koranteng, K., Mukwaya, P. I., & Taylor, A. (2022). Power dynamics in transdisciplinary research for sustainable urban transitions. *Environmental Science and Policy*, 131, 135–142. <https://doi.org/10.1016/j.envsci.2022.02.001>
- Katz, S. J., & Martin, B. R. (1997). What is research collaboration? *Research Policy*, 26, 1–18.
- Klein, J. T. (2015). Reprint of “Discourses of transdisciplinarity: Looking back to the future”. *Futures*, 65, 10–16. <https://doi.org/10.1016/j.futures.2015.01.003>
- Knapp, C. N., Reid, R. S., Fernández-Giménez, M. E., Klein, J. A., & Galvin, K. A. (2019). Placing transdisciplinarity in context: A review of approaches to connect scholars, society and action. *Sustainability (Switzerland)*, 11(18), 4899. <https://doi.org/10.3390/su11184899>
- Kok, K. P. W., Gjefsen, M. D., Regeer, B. J., & Broerse, J. E. W. (2021). Unraveling the politics of ‘doing inclusion’ in transdisciplinarity for sustainable transformation. *Sustainability Science*, 16(6), 1811–1826. <https://doi.org/10.1007/s11625-021-01033-7>
- Lacy, R. C., Miller, P. S., Nyhus, P. J., Pollak, J. P., Raboy, B. E., & Zeigler, S. L. (2013). Metamodels for transdisciplinary analysis of wildlife population dynamics. *PLoS ONE*, 8(12), e84211. <https://doi.org/10.1371/journal.pone.0084211>
- Lane, S. N., Odoni, N., Landstrom, C., Whatmore, S. J., Ward, N., & Bradley, S. (2011). Doing flood risk science differently: An experiment in radical scientific method. *Transactions of the Institute of British Geographers NS*, 36, 15–36. <https://doi.org/10.1111/j.1475-5661.2010.00410.x>
- Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C. J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science*, 7 (SUPPL. 1), 25–43. <https://doi.org/10.1007/s11625-011-0149-x>
- Lau, L., & Pasquini, M. W. (2004). Meeting grounds: Perceiving and defining interdisciplinarity across the arts, social sciences and sciences. *Interdisciplinary Science Reviews*, 29, 49–64. <https://doi.org/10.1179/030801804225012437>
- Lemos, M. C., & Morehouse, B. J. (2005). The co-production of science and policy in integrated climate assessments. *Global Environmental Change*, 15, 57–68. <https://doi.org/10.1016/j.gloenvcha.2004.09.004>
- Lieberknecht, K., Houser, H., Rabinowitz, A., Pierce, S. A., Rodríguez, L., Leite, F., Lowell, J., & Gray, J. N. (2022). Creating meeting grounds for transdisciplinary climate research: The role of humanities and social sciences in grand challenges. *Interdisciplinary Science Reviews*. <https://doi.org/10.1080/03080188.2022.2148889>
- Luks, F., & Siebenhüner, B. (2007). Transdisciplinarity for social learning? The contribution of the German socio-ecological research initiative to sustainability governance. *Ecological Economics*, 63(2-3), 418–426. <https://doi.org/10.1016/j.ecolecon.2006.11.007>
- Lux, A., Schäfer, M., Bergmann, M., Jahn, T., Marg, O., Nagy, E., Ransiek, A.-C., & Theiler, L. (2019). Societal effects of transdisciplinary sustainability research – how can they be strengthened during the research process? *Environmental Science and Policy*, 101, 183–191. <https://doi.org/10.1016/j.envsci.2019.08.012>
- Lyall, C., Meagher, L., & Bruce, A. (2015). A rose by any other name? Transdisciplinarity in the context of UK research policy. *Futures*, 65, 150–162. <https://doi.org/10.1016/j.futures.2014.08.009>
- Lyon, F. (1996). How farmers research and learn: The case of arable farmers in East Anglia, UK. *Journal of Agriculture and Human Values*, 13(4), 39–47.
- Mauz, I., Peltola, T., Granjou, C., van Bommel, S., & Buijs, A. (2012). How scientific visions matter: Insights from three long-term socio-ecological research (LTSER) platforms under construction in Europe. *Environmental Science and Policy*, 19–20, 90–99. <https://doi.org/10.1016/j.envsci.2012.02.005>
- Max-Neef, M. A. (2005). Foundations of transdisciplinarity. *Ecological Economics*, 53(1), 5–16. <https://doi.org/10.1016/j.ecolecon.2005.01.014>
- Maynard, C. M. (2013). How public participation in river management improvements is affected by scale. *Area*, 45(2), 230–238. <https://doi.org/10.1111/area.12015>
- Mertens, F., Távora, R., Santandreu, A., Luján, A., Arroyo, R., & Saint-Charles, J. (2022). Participation and transdisciplinarity in Ecohealth: a social

- network analysis perspective [Participação e transdisciplinaridade em Ecosáude: a perspectiva da análise de redes sociais]. *Saude e Sociedade*, 31(3), e190903en. <https://doi.org/10.1590/s0104-12902022190903en>
- Mitchell, M., Moore, S. A., Clement, S., Lockwood, M., Anderson, G., Gaynor, S. M., Gilfedder, L., Rowe, R., Norman, B., & Lefroy, E. C. (2017). Biodiversity on the brink: Evaluating a transdisciplinary research collaboration. *Journal for Nature Conservation*, 40, 1–11. <https://doi.org/10.1016/j.jnc.2017.08.002>
- Nicolescu, B. (2002). *Manifesto of transdisciplinarity*. State University of New York Press.
- Nooteboom, B. (1999). Innovation and inter-firm linkages: New implications for policy. *Research Policy*, 28, 793–805. [https://doi.org/10.1016/S0048-7333\(99\)00022-0](https://doi.org/10.1016/S0048-7333(99)00022-0)
- Norris, P. E., O'Rourke, M., Mayer, A. S., & Halvorsen, K. E. (2016). Managing the wicked problem of transdisciplinary team formation in socio-ecological systems. *Landscape and Urban Planning*, 154, 115–122. <https://doi.org/10.1016/j.landurbplan.2016.01.008>
- Phillipson, J., Lowe, P., Proctor, A., & Ruto, E. (2012). Stakeholder engagement and knowledge exchange in environmental research. *Journal of Environmental Management*, 95, 56–65. <https://doi.org/10.1016/j.jenvman.2011.10.005>
- Plummer, R., Blythe, J., Gurney, G. G., Witkowski, S., & Armitage, D. (2022). Transdisciplinary partnerships for sustainability: An evaluation guide. *Sustainability Science*, 17(3), 955–967. <https://doi.org/10.1007/s11625-021-01074-y>
- Podesta, G. P., Natenzon, C. E., Hidalgo, C., & Toranzo, F. R. (2013). Interdisciplinary production of knowledge with participation of stakeholders: A case study of a collaborative project on climate variability, human decisions and agricultural ecosystems in the Argentine Pampas. *Environmental Science and Policy*, 26, 40–48. <https://doi.org/10.1016/j.envsci.2012.07.008>
- Pohl, C. (2005). Transdisciplinary collaboration in environmental research. *Futures*, 37(10), 1159–1178. <https://doi.org/10.1016/j.futures.2005.02.009>
- Pohl, C. (2008). From science to policy through transdisciplinary research. *Environmental Science and Policy*, 11, 46–53. <https://doi.org/10.1016/j.envsci.2007.06.001>
- Pohl, C., Rist, S., Zimmermann, A., Fry, P., Gurung, G. S., Schneider, F., Ifejika Speranza, C., Kiteme, B., Boillat, S., Serrano, E., Hirsch Hadorn, G., & Wiesmann, U. (2010). Researchers' roles in knowledge co-production: Experience from sustainability research in Kenya, Switzerland, Bolivia and Nepal. *Science and Public Policy*, 37(4), 267–281. <https://doi.org/10.3152/030234210X496628>
- Polk, M. (2015). Transdisciplinary co-production: Designing and testing a transdisciplinary research framework for societal problem solving. *Futures*, 65, 110–122. <https://doi.org/10.1016/j.futures.2014.11.001>
- Popa, F., Guillermin, M., & Dedeurwaerdere, T. (2015). A pragmatist approach to transdisciplinarity in sustainability research: From complex systems theory to reflexive science. *Futures*, 65, 45–56. <https://doi.org/10.1016/j.futures.2014.02.002>
- Price, H. D., Bowyer, C. J., Büker, P., Gray, C. M., Hahn, M., Lambe, F., Loh, M., Medcalf, A. J., Njoora, T. K., Waelde, C., Wainwright, M., & West, S. E. (2023). From reflection diaries to practical guidance for transdisciplinary research: Learnings from a Kenyan air pollution project. *Sustainability Science*, 18(3), 1429–1444. <https://doi.org/10.1007/s11625-023-01317-0>
- Radinger-Peer, V., Schuppenlehner-Kloyber, E., Penker, M., & Gugerell, K. (2022). Different perspectives on a common goal? The Q-method as a formative assessment to elucidate varying expectations towards transdisciplinary research collaborations. *Sustainability Science*, 17(6), 2459–2472. <https://doi.org/10.1007/s11625-022-01192-1>
- Rafols, I., Leydesdorff, L., O'Hare, A., Nightingale, P., & Stirling, A. (2012). How journal rankings can suppress interdisciplinary research: A comparison between innovation studies and business & management. *Research Policy*, 41(7), 1262–1282. <https://doi.org/10.1016/j.respol.2012.03.015>
- Raymond, C. M., Fazey, I., Reed, M. S., Stringer, L. C., Robinson, G. M., & Evely, A. C. (2010). Integrating local and scientific knowledge for environmental management. *Journal of Environmental Management*, 91, 1766–1777. <https://doi.org/10.1016/j.jenvman.2010.03.023>
- Reed, M. G., & Abernethy, P. (2018). Facilitating co-production of transdisciplinary knowledge for sustainability: Working with Canadian biosphere reserve practitioners. *Society and Natural Resources*, 31(1), 39–56. <https://doi.org/10.1080/08941920.2017.1383545>
- Renner, R., Schneider, F., Hohenwallner, D., Kopeinig, C., Kruse, S., Lienert, J., Link, S., & Muhar, S. (2013). Meeting the challenges of transdisciplinary knowledge production for sustainable water governance. *Mountain Research and Development*, 33(3), 234–247. <https://doi.org/10.1659/MRD-JOURNAL-D-13-00002.1>
- Rinaldi, P. N. (2023). Dealing with complex and uncertain futures: Glimpses from transdisciplinary water research. *Futures*, 147, 103113. <https://doi.org/10.1016/j.futures.2023.103113>
- Rockström, J., Gupta, J., Qin, D., Lade, S. J., Abrams, J. F., Andersen, L. S., Armstrong McKay, D. I., Bai, X., Bala, G., Bunn, S. E., Ciobanu, D., De Clerck, F., Ebi, K., Gifford, C., Gordon, C., Hasan, S., Kanie, N., Lenton, T. M.S., ... Zhang, X. (2003). Safe and just Earth system boundaries. *Nature*, 619, 102–111. <https://doi.org/10.1038/s41586-023-06083-8>
- Romero-Lankao, P., Borbor-Cordova, M., Abrutsky, R., Gunthers, G., Behrenz, E., & Dawidowsky, L. (2013). ADAPTE: A tale of diverse teams coming together to do issue-driven interdisciplinary research. *Environmental Science and Policy*, 26, 29–39. <https://doi.org/10.1016/j.envsci.2011.12.003>
- Roux, D. J., Stirzaker, R. J., Breen, C. M., Lefroy, E. C., & Cresswell, H. P. (2010). Framework for participative reflection on the accomplishment of transdisciplinary research programs. *Environmental Science and Policy*, 13(8), 733–741. <https://doi.org/10.1016/j.envsci.2010.08.002>
- Scharff, R. C., & Stone, D. A. (2022). Transdisciplinarity without method: On being interdisciplinary in a technoscientific world. *Human Studies*, 45(1). <https://doi.org/10.1007/s10746-021-09616-0>
- Schuppenlehner-Kloyber, E., & Penker, M. (2015). Managing group processes in transdisciplinary future studies: How to facilitate social learning and capacity building for self-organised action towards sustainable urban development? *Futures*, 65, 57–71. <https://doi.org/10.1016/j.futures.2014.08.012>
- Schmidt, L., & Pröpper, M. (2017). Transdisciplinarity as a real-world challenge: A case study on a North–South collaboration. *Sustainability Science*, 12(3), 365–379. <https://doi.org/10.1007/s11625-017-0430-8>
- Scholz, R. W., & Steiner, G. (2015a). The real type and ideal type of transdisciplinary processes: Part I – theoretical foundations. *Sustainability Science*, 10(4), 527–544. <https://doi.org/10.1007/s11625-015-0326-4>
- Scholz, R. W., & Steiner, G. (2015b). The real type and ideal type of transdisciplinary processes: Part II – what constraints and obstacles do we meet in practice? *Sustainability Science*, 10(4), 653–671. <https://doi.org/10.1007/s11625-015-0327-3>
- Schönenberg, R., Boy, J., Hartberger, K., Schumann, C., Guggenberger, G., Siebold, M., Lakes, T., Lamparter, G., Schindewolf, M., Schaldach, R., Nendel, C., Hohnwald, S., Meurer, K. H. E., Gerold, G., & Klingler, M. (2017). Experiences of inter- and transdisciplinary research—a trajectory of knowledge integration within a large research consortium. *Erdkunde*, 71(3), 177–193. <https://doi.org/10.3112/erdkunde.2017.03.02>
- Shackleton, S., Taylor, A., Gammage, L., Gillson, L., Sitas, N., Methner, N., Barmand, S., Thorn, J., McClure, A., Cobban, L., Jarre, A., & Odume, O. N. (2023). Fostering transdisciplinary research for equitable and sustainable development pathways across Africa: What changes are needed? *Ecosystems and People*, 19(1). <https://doi.org/10.1080/26395916.2022.2164798>
- Shrivastava, P., Ivanaj, S., & Persson, S. (2013). Transdisciplinary study of sustainable enterprise. *Business Strategy and the Environment*, 22(4), 230–244. <https://doi.org/10.1002/bse.1773>
- Siebenhüner, B. (2018). Conflicts in transdisciplinary research: Reviewing literature and analysing a case of climate adaptation in northwestern Germany. *Ecological Economics*, 154, 117–127. <https://doi.org/10.1016/j.ecolecon.2018.07.011>
- Siew, T. F., Aenis, T., Spangenberg, J. H., Nauditt, A., Doll, P., Frank, S. K., Ribbe, L., Rodriguez-Labajos, B., Rumbaur, C., Settele, J., & Wang, J. (2016). Transdisciplinary research in support of land and water management in China and Southeast Asia: Evaluation of four research projects. *Sustainability Science*, 11(813), 813–829. <https://doi.org/10.1007/s11625-016-0378-0>
- Simon, D., & Schiemer, F. (2015). Crossing boundaries: Complex systems, transdisciplinarity and applied impact agendas. *Current Opinion in Environmental Sustainability*, 12, 6–11. <https://doi.org/10.1016/j.cosust.2014.08.007>

- Strand, M., Ortega-Cisneros, K., Niner, H. J., Wahome, M., Bell, J., Currie, J. C., Hamukuaya, H., La Bianca, G., Lancaster, A. M. S. N., Maseka, N., McDonald, L., McQuaid, K., Samuel, M. M., & Winkler, A. (2022). Transdisciplinarity in transformative ocean governance research – reflections of early career researchers. *ICES Journal of Marine Science*, 79(8), 2163–2177. <https://doi.org/10.1093/icesjms/fsac165>
- Swan, J., Bresnen, M., Robertson, M., Newell, S., & Dopson, S. (2010). When policy meets practice: Colliding logics and the challenges of ‘Mode 2’ initiatives in the translation of academic knowledge. *Organization Studies*, 31(9–10), 1311–1340. <https://doi.org/10.1177/0170840610374402>
- Taylor, A., Pretorius, L., McClure, A., Iiping, K. N., Mwalukanga, B., & Mamombe, R. (2021). Embedded researchers as transdisciplinary boundary spanners strengthening urban climate resilience. *Environmental Science and Policy*, 126, 204–212. <https://doi.org/10.1016/j.envsci.2021.10.002>
- Thomas, S., Richter, M., Lestari, W., Prabawaningtyas, S., Anggoro, Y., & Kuntoadji, I. (2018). Transdisciplinary research methods in community energy development and governance in Indonesia: Insights for sustainability science. *Energy Research and Social Science*, 45, 184–194. <https://doi.org/10.1016/j.erss.2018.06.021>
- Thorén, H., & Breian, L. (2016). Stepping stone or stumbling block? Mode 2 knowledge production in sustainability science. *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences*, 56, 71–81. <https://doi.org/10.1016/j.shpsc.2015.11.002>
- Thornton, P. H., Ocasio, W., & Lounsbury, M. (2012). *The institutional logics perspective: A new approach to culture, structure, and process*. Oxford University Press.
- Toomey, A. H., Knight, A. T., & Barlow, J. (2017). Navigating the space between research and implementation in conservation. *Conservation Letters*, 10(5), 1–7. <https://doi.org/10.1111/conl.12315>
- Trencher, G., Yarime, M., McCormick, K., Doll, C., & Kraines, S. (2014). Beyond the third mission: Exploring the emerging university function of co-creation for sustainability. *Science and Public Policy*, 41(2), 151–179. <https://doi.org/10.1093/scipol/sct044>
- Tschakert, P., Tuana, N., Westskog, H., Koelle, B., & Afrika, A. (2016). TCHANGE: The role of values and visioning in transformation science. *Current Opinion in Environmental Sustainability*, 20, 21–25. <https://doi.org/10.1016/j.cosust.2016.04.003>
- van der Hel, S. (2016). New science for global sustainability? The institutionalisation of knowledge co-production in future earth. *Environmental Science and Policy*, 61, 165–175. <https://doi.org/10.1016/j.envsci.2016.03.012>
- Wardani, J., Bos, J. J., Ramirez-Lovering, D., & Capon, A. G. (2022). Enabling transdisciplinary research collaboration for planetary health: Insights from practice at the environment-health-development nexus. *Sustainable Development*, 30(2), 375–392. <https://doi.org/10.1002/sd.2280>
- Wiek, A., Withycombe, L., & Redman, C. L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6, 203–218. <https://doi.org/10.1007/s11625-011-0132-6>
- Williams, P. (2002). The competent boundary spanner. *Public Administration*, 80, 103–124. <https://doi.org/10.1111/1467-9299.00296>
- Wilsdon, J., Wynne, B., & Stilgoe, J. (2005). *The public value of science: Or how to ensure that science really matters*. Demos.
- Wueller, G., & Pohl, C. (2016). How researchers frame scientific contributions to sustainable development: A typology based on grounded theory. *Sustainability Science*, 11, 789–800. <https://doi.org/10.1007/s11625-016-0363-7>
- Yusuf, S. (2008). Intermediating knowledge exchange between universities and businesses. *Research Policy*, 37, 1167–1174. <https://doi.org/10.1016/j.respol.2008.04.011>