3 Transdisciplinary research

Approaches and methodological principles

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3.1 Introduction

Transdisciplinary research is grounded in a pluralist epistemology (Söderbaum, 2009; Vildåsen et al., 2017) that asserts the role of multiple values and ideologies in knowledge creation (Hessels and van Lente, 2008). By the co-production of knowledge between academics and non-academics (Pohl et al., 2010), transdisciplinary research aims at meaningful outcomes for both science and society. In Chapter 2, we described various 'tastes' in transdisciplinary research, which balance three distinct ambitions in different ways: complex system knowledge integration; addressing the persistency of wicked societal problems; and empowerment in the light of urgent transformational challenges. These ambitions each share the need to connect academic and non-academic actors in the process of producing applicable knowledge in the context of urgent sustainability challenges. Transdisciplinary research, therefore, pushes scientific research to leave the academic arena with an exclusive academic research culture and aims to search for direct contributions to societal transitions by applying co-production of knowledge with non-academic stakeholders. The contribution of scientific research to societal challenges raises expectations on, among others, the role of scientific work (Carayannis et al., 2016; Gibbons et al., 1994; Hessels and van Lente, 2008; see also the discussion on 'mode 1' knowledge production in Chapter 2). In this third chapter, we address the methodological implications of transdisciplinary research. For this, we first need to reflect on the contextual practice of transdisciplinary research.

Traditional scientific research approaches leading to 'mode 1' knowledge creation, as explained in Chapter 2, entail experimental research or validation of theory describing isolated phenomena, based on quantitative measurements providing merely statistical evidence. Also required is qualitative research, where researchers position themselves as external spectators of social phenomena (see opening quote in Chapter 1), while assuring the need for internal or external validity. Standard academic trajectories (i.e. funded research projects executed by professors, post-docs or PhDs) aiming at 'mode 1' knowledge creation merely operate in prearranged teams, working on a predefined scope and to a strict time plan, due to predetermined financial budgets and the empirical cycle (Hessels and

van Lente, 2008). In contrast to this, transdisciplinary research, while contributing to societal transitions, looks for answers to societal problems or challenges using knowledge of non-academic actors in addition to academic actors' knowledge. Transdisciplinary research, therefore, aims for both construct and field validity, thus going beyond traditional formal scientific evidence (Cash et al., 2003; Jahn et al., 2012; Pohl and Hirsch Hadorn, 2008). Merging knowledge from different actors creates enhanced understanding of the societal problems and challenges necessary for making strategic decisions to start a process of change that contributes to the societal transition at hand.

Exposure to different sources of knowledge requires researchers to be receptive to alternative mono-, inter- and/or multidisciplinary perspectives, and able to coordinate the change process that transdisciplinarity entails. This brings them into dual positions: they are both *experts* and *knowledge brokers*. Consequently, transdisciplinary researchers collect, value and integrate the knowledge needed to lead the transdisciplinary research to contribute to societal changes (Lopes and Videira, 2019; Zscheischler et al., 2017). In practice, transdisciplinary researchers also work with external funding or combine research with education, matching demands from a diverse group of stakeholders (e.g. scientific funding bodies, private funding bodies, educational bodies; Campbell et al., 2015; Wiek and Lang, 2016). Thus, transdisciplinary research projects are confronted by complex and sometimes even strict time planning in order to comply with the demands of the different stakeholders.

To enable contribution to societal challenges, transdisciplinary research entails a research approach that is broader than the individual research projects themselves: it is about the (portfolio of) research projects that generate knowledge on the societal challenge at hand, the roles that different actors play and the research strategy that is applied. For some examples of academic institutions that aim to contribute to societal issues through their transdisciplinary research portfolios and projects, see Sue McGregor's work on transversities (McGregor and Volckmann, 2013). For discussing methods, as seen from this context of the research practice of transdisciplinary scholars, we need to zoom out from individual research projects with their particular goals and aims to the wider research strategy of transdisciplinary researchers and their institutes, aiming at contribution to challenges in society at large. Transdisciplinary research, especially when going from selective to extended stakeholder engagement, is multi-levelled (see Figure 3.1): a single transdisciplinary project research even of limited scope can contribute to broad societal challenges when the single project outcomes are reflected in a broader portfolio of transdisciplinary projects or even a transdisciplinary research institute strategy. A consistent and/or coherent linking of goal and scope of transdisciplinary research between these levels enables a successful contribution to societal challenges and multidisciplinary knowledge creation as well as to methodological knowledge and experience built up on how to execute transdisciplinary research scientifically. Moreover, a clear vision and strategy on transdisciplinary research from the institute can help to generate synergy between the projects within the portfolio and, therefore, further the success of the contribution to societal issues.

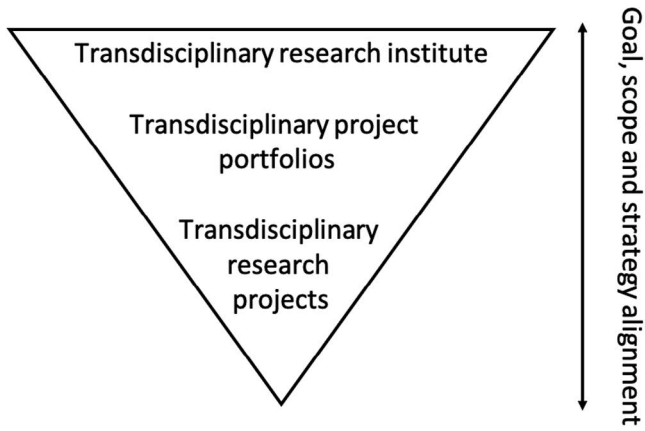

Figure 3.1 The multi-level perspective on transdisciplinary research

The methods applied for transdisciplinary research entail more than the process of data collection, data analysis, etc. It is also the process of organizing the network of necessary knowledge carriers – the academic and non-academic actors – and the strategic choices that lead to a contribution to societal developments of the transdisciplinary research project, the transdisciplinary project portfolio or the transdisciplinary research institute. This has implications for the research tools applied in transdisciplinary research while aiming for a contribution to meaningful outcomes for practice and science. In the next section, we will first discuss the commonly shared ideas on the architecture of such open and flexible transdisciplinary research processes, and then in section 3.3 we will discuss the main methodological principles applied in transdisciplinary research. In section 3.4, we will give an overview of available transdisciplinary tools. The chapter will conclude with some considerations.

3.2 A flexible and open process organization

Transdisciplinary research consists of tools and methods that integrate a thorough process of knowledge production and a connected creative process of developing interventions in a given system. Consequently, transdisciplinary research consists of two supporting cycles (see Figure 3.2): the scientific cycle of the production of knowledge based on curiosity (i.e. leading to meaningful outcomes for science), and the practical cycle of the development of interventions for societal problems (i.e. leading to meaningful outcomes for practice).

3.2.1 The scientific cycle of transdisciplinarity

A tension between creativity and verification lies at the heart of most theories of scientific inquiry. Creativity and verification play complementary roles in different

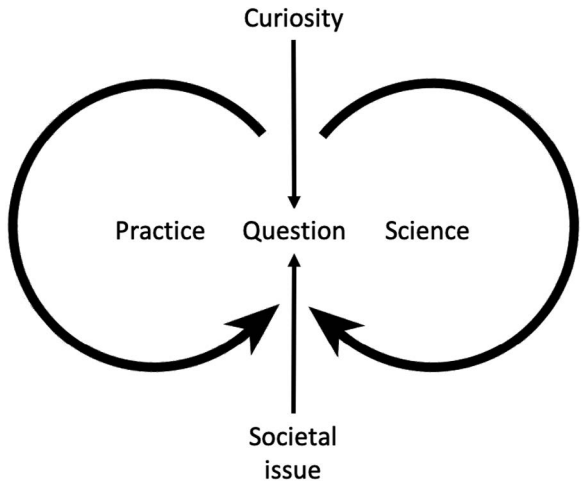

Figure 3.2 The intertwined cycle of transdisciplinary research: the practical and the scientific cycle

stages of the scientific process. Creative processes benefit from having a reliable knowledge base, which is something that the verification process in the scientific cycle helps to establish. The 'empirical cycle of growth of knowledge' developed by (Groot, 1994; Groot and Spiekerman, 1969) defines empirical research as mainly based on a cycle which starts with a *question* originating from curiosity (for example, from the need for enhanced understanding) and then follows the steps of theory, hypotheses, method, data, analysis, discussion and conclusion (see Figure 3.3). The quest for new knowledge is first reflected upon by reviewing the literature for *theory* at hand, resulting in *hypotheses* that could give direction for finding an answer to the research question (Knight and Cross, 2012).

> The construction of hypotheses about possible associations in reality is principally considered a 'free' activity. . . . Only when this freedom is respected will room remain for the brilliant insight, for the imagination of the researcher.
>
> (de Groot and Spiekerman (1969) as cited by Wagenmakers et al., 2018)

The *method* that will guide the collection, *analysis* and synthesis of the research *data* ensures the quality of the data and enables the critical representation of the research data. The *discussion* explains the contribution to science of the research, which is supported by reflecting on the synthesis of the research data in light of debates in literature related to the research. The *conclusion* of the research on content as well as method gives responses to the research question. Consequently, the inductive assessment of the outcome results in an updated knowledge base, after which the empirical cycle starts anew (Wagenmakers et al., 2018). The knowledge

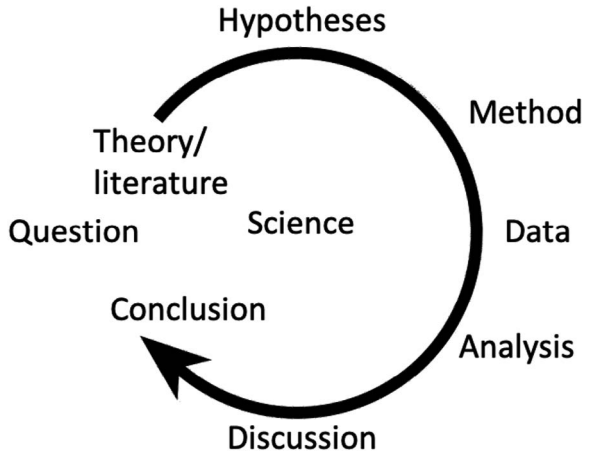

Figure 3.3 The empirical cycle based on de Groot (Groot, 1994; Groot and Spiekerman, 1969)

produced by this empirical research cycle contributes to 'mode 1' knowledge production and is useful for validating or to some extent even generalizing knowledge (e.g. theories, models).

Collaborative transdisciplinarity aiming at co-production of practical and scientific knowledge is becoming more common in the philosophy of science and the management discipline (Balsiger, 2015). With ongoing societal challenges, there is a demand for continuous development of multidisciplinary theories (Lang et al., 2012; Pohl et al., 2010). Efforts to understand ongoing societal developments, with their very high levels of uncertainty, have disclosed the limitations of conventional scientific mono-, inter- and even multidisciplinary approaches to theory testing. Already available research from mono-, inter- and multidisciplinary research based on the collaboration between academic actors reflecting on societal developments from different perspectives also creates an applicable knowledge base for transdisciplinary research. Consequently, transdisciplinary research is still in the 'mode 1' production of knowledge, as discussed in Chapter 2, and therefore the collaboration between academic actors from different disciplinary backgrounds is key for the success of transdisciplinarity.

As transdisciplinary research starts from a societal challenge, the curiosity and research question are directly linked to a question of societal actors. Transdisciplinary research is driven by the empirical cycle of knowledge creation in academia and a practical cycle of developing new options for societal problems. It is the combination or linking of these two cycles of science and practice that enables transdisciplinarity to produce new knowledge and develop interventions to contribute to societal challenges. These joint cycles correspond to what Lang et al. (2012) call the societal practice pathways and the scientific practice of transdisciplinary research: the practice cycle is pledged to the exploration of new options

for solving societal challenges and questions; the scientific cycle is pledged to the production of knowledge by developing multi- and interdisciplinary approaches, transdisciplinary research methods and general insights related to the field of the societal challenge. Linking both cycles is crucial for transdisciplinary research (Bergmann et al., 2010) to contribute to meaningful outcomes for the practical and scientific question at stake but, most importantly, to contribute to the societal challenge.

3.2.2 The practical cycle of transdisciplinarity

The practical cycle starts with the identification and description of the real-world problem, formulating agreed upon, societally relevant questions and building a team or consortium (Lang et al., 2012) for identifying and developing possible interventions. After the application of these interventions, the evaluation phase shows whether the practical question at hand has been answered. Depending on the choice for the transdisciplinary taste (see Figure 2.6), the evaluation of the interventions is on a project, portfolio or institute level. As such, the meaningful outcomes for practice and science are evaluated based on their contribution, using societally relevant questions (i.e. project or portfolio) or societal challenges (i.e. portfolio or institute).

In this way, doing transdisciplinary research links closely to design thinking, the theory of inventive problem or systematic innovation. This link is supported by sustainability scholars from other social science backgrounds (for example, Escobar, 2011, 2018 – anthropology; Welsh and Dehler, 2012 – management education; Kuijer, 2014 – social practice theory), presenting design theory and practice with the aim of channelling design's world-making capacity towards a more sustainable society. Design theory aims to put knowledge to work to get the right solution to the problem. Or, as Von Oech (1983, p. 38) puts it:

> Knowledge is the stuff from which new ideas are made. Nonetheless, knowledge alone won't make a person creative. I think that we've all known people who knew lots of facts and nothing creative happened. Their knowledge just sat in their crania because they didn't think about what they knew in any new ways. Thus, the real key to being creative lies in what we do with our knowledge.

Design thinking, as an activity of solving complex problems (Buchanan, 1992), can be understood through the search skills of information, creation and organization of knowledge, decision-making, learning and problem solving. Design thinking is a set of mental processes aimed at interventions to solve complex problems, in particular social sciences (Buchanan, 1992). Design thinking challenges the traditional line of analytical thinking that fragments the processes and examines them by specificity. Design thinking involves dynamic processes characterized by collaborative and systemic views, integrating interdisciplinary elements and knowledge, and is, therefore, apt to be applied in a transdisciplinary

research approach to support the process of transforming the knowledge produced in the scientific cycle into interventions. The usefulness of these contributions to practice serve as feedback of the usefulness of scientific knowledge (Boland and Collopy, 2004; Nobre and Biscaia, 2015).

One of the common ways of describing the design thinking process is as consisting of four steps with iteration loops (Cross, 2011; Mueller-Roterberg, 2018; see Figure 3.4):

1 *Exploration*

In this first step, a collaboration between stakeholders (i.e. problem owners as well as actors engaged in solving the issue at hand) aims at understanding the question and the underlying societal issue. In transdisciplinary research, the knowledge from the scientific cycle contributes to this understanding;

2 *Idea/concept generation*

In this second step, the collaboration between different stakeholders starts with generating ideas on potential interventions. The concepts developed are at a draft stage, detailed enough to be assessed in the next step;

3 *Evaluation*

In this third step, a reflection between the actors leads to an assessment and selection of the draft intervention possibilities, leading to a limited number of concepts that will be developed and selected for possible application. The collective understanding of the question and underlying issue coming from the scientific cycle and the first step, exploration, is used for setting the assessment criteria;

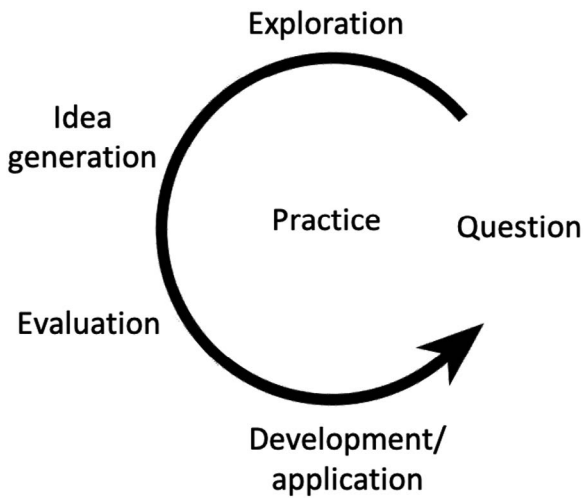

Figure 3.4 The practice cycle

4 *Definite development and application*

In this final step, the selected intervention will be made final through detailed drawings, prototypes, plans, details, specifications, etc., and the interventions will be applied.

3.2.3 The integrated cycle of transdisciplinary research

By combining the practical and scientific cycle, transdisciplinary research is not just about advancing scientific understanding or theory; it launches the assumption that scientific knowledge created by academic actors, together with knowledge of non-academic actors, is by itself a powerful agent of change, placing science at the centre of transformative changes (Moser, 2016). Thus, transdisciplinary research often requires coping with different interpretations of the core concept of 'transformation' across disciplines, groups of actors with their sectorial, regional or even cultural specificities, as well as with the very understanding of science and its role in society.

When combining the practical and scientific cycles (see Figure 3.5) from a multi-actor and collaboration view, the real-world problem should be translated into a boundary object (see e.g. Clark et al., 2016) that is both researchable and allows for the re-integration of the insights into the scientific body of knowledge as well as interventions in practice (Lang et al., 2012). Curiosity and the societal issue at hand drive the question as a centre focus. The combination of both cycles implies that academic and non-academic actors together have to go through both cycles in order to reach meaningful outcomes for practice and science.

Multi-actor collaboration during transdisciplinary research has consequences for the scientific cycle of knowledge development as well as for the practical

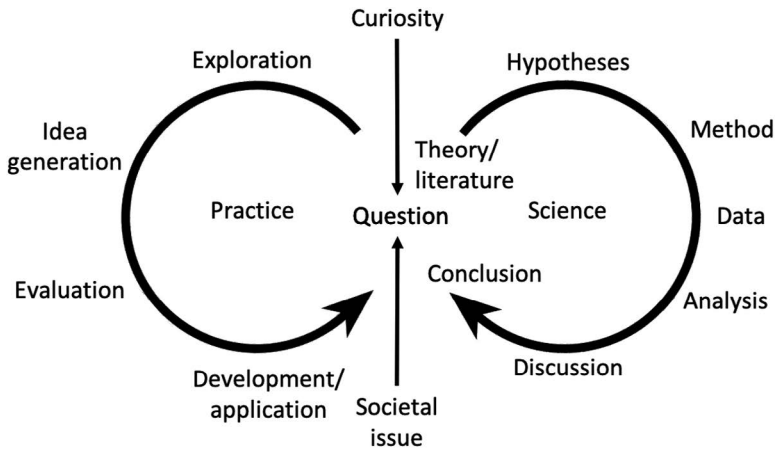

Figure 3.5 The cycle of transdisciplinary research

cycle of intervention development: for example, theory development in transdisciplinary research values knowledge from science, as well as practice creating a broader basis for hypothesis development. The consequences for methods and transdisciplinary research tools can be found in the next sections. The analysis and discussion of the research data consist of a collaborative reflective process aimed at field validity: the fact that the research outcomes can be used by the academic actors facing the societal issue. The enhanced understanding by the academic and non-academic actors of the societal issue coming from the scientific cycle is used to explore and generate intervention ideas or concepts collectively. Consequently, the evaluation of these intervention options is performed from both a scientific and a practical perspective, confirming the practical usefulness of the knowledge created in the scientific cycle. Finally, the continuous collaboration between academic and non-academic actors (see Figure 3.6) in the application of the interventions ensures the input for the scientific cycle as to whether field validity has effectively worked; this makes the transdisciplinary cycle a continuous process of learning of the creation of knowledge and interventions to contribute to societal challenges.

In the continuous collaboration throughout the transdisciplinary research process, it is essential that key decision-makers are continuously attached to this double cyclical process so that implementation of the developed interventions in society is ensured. For the transdisciplinary researchers themselves, being one of the principal actors requires them to deal with the paradox between focusing on the content and focusing on the coordination of the project and its actors: while

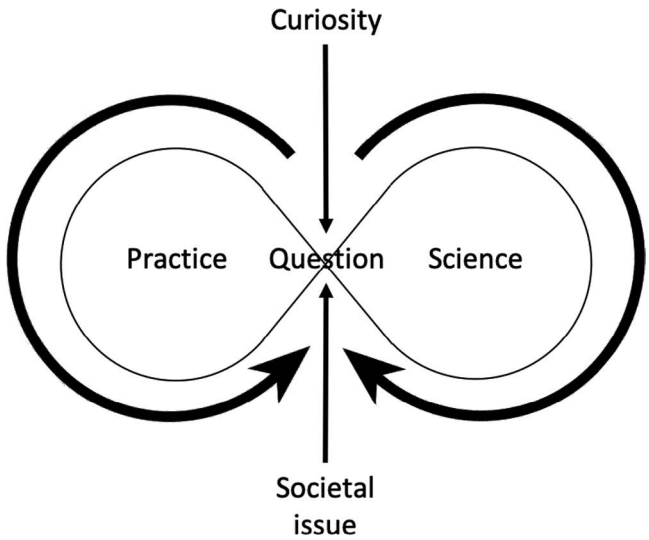

Figure 3.6 The continuous collaboration between academic and non-academic actors to ensure the transdisciplinary research process

contributing to the development of knowledge and/or interventions, the transdisciplinary researcher is the main actor responsible for coordinating the overall process, including project and time management, to ensure the collaboration between the different actors.

This also depends on the type of transdisciplinary research: for example, small range transdisciplinarity (see section 2.3) involves a limited group of actors. The coupling of both cycles enables the enrichment of scientific theory based on 'mode 1' knowledge production with field theory coming from stakeholders' experiences in practice. Theory development in transdisciplinary research is based on validated and non-validated (experience) knowledge. Consequently, the validation of knowledge is based on the successful usage of the outcomes of the transdisciplinary research in practice instead of internal/external validity as is the case with 'mode 1' knowledge creation. Due to the multi-level character of transdisciplinary research, there should be a multi-level validation check: what is meaningful within a project should be checked on a research portfolio and institutional level as well. Transdisciplinary research of both the practical and scientific cycle implies a synchronization of the scientific method and practical experiment/idea generation for the intervention to be successful.

3.3 The process steps of transdisciplinary research

As the integration of both cycles from Figure 3.6 is necessary for transdisciplinary research to reach its aim, we present a six-step model for transdisciplinary research, enabling the co-creation and designing of meaningful outcomes for practice and science contributing to societal challenges:

1 *Research vision and strategy*

   Considering the research portfolio of and the contribution to the societal challenge, the researcher or research institute aims to define the goal and scope of the project at hand. The development of the research vision and strategy includes aligning demands from academic and non-academic actors;

2 *Problem exploration and structuring*

   The goal and scope of the transdisciplinary research project is explored and detailed by collaborating with direct actors facing the societal challenge. The hunch (i.e. abduction) of academic and non-academic actors related to this step of the transdisciplinary research is crucial;

3 *System understanding*

   Based on the problem addressed by the project team, the application of grounded theory leads to an exploration in practice and theory. An enhanced understanding of the system as a whole clarifies challenges considering the scope and goal of the project;

4 *Search and compare solutions*

A creative process with different actors, based on the understanding of the full system, leads to the design and comparison of solutions for the problem or challenge at hand;

5 *Choose, decide and prepare for application*

After the selection of the direction of the solution, the strategic, tactic and operational activities are set up to apply and implement the solution;

6 *Synthesis and feedback with overall vision and strategy*

In this final step, the meaningfulness of the outcomes of the project and the contribution to society and science is discussed at the content, process and strategy levels: did the project contribute to meeting the specific societal problem? Did the project outcomes advance debates in literature on the topic and/or the methodological approach? And did the project support the strategy of the transdisciplinary researcher and/or transdisciplinary research institute to directly contribute to the sustainable development of society? See here the link back to step 1.

Following these six steps, a transdisciplinary research architecture includes strategic questioning at multiple levels (project, portfolio and institute; see Figure 3.1), connecting the vision of the academic institution regarding its contribution to societal challenges to the specific projects. To offer guidance on the generation of meaningful outcomes for science and practice in the collaborative process between academic and non-academic actors, the overall transdisciplinary architecture discussed in Chapter 2 enables us to identify a common approach, at least for *intra-academic transdisciplinarity* and *fairness-driven transdisciplinarity*, with their stakeholder engagement aiming for commitment, creation and/or empowerment. The six steps described allow us to synthesize various suggested approaches in literature. A widely known Swiss–Austrian group of scholars described the generation of meaningful outcomes for science and practice as a combination of 'forward operating' and 'backward planning', applying five steps in both directions (Scholz et al., 2006), rooting it in literature about 'backcasting' (Dreborg, 1996; Holmberg and Robert, 2011). In their 2008 handbook and some connected publications, Hirsch Hadorn et al. (2008) describe the process as consisting of three phases: 'problem identification and problem structuring'; 'problem analysis'; and 'bringing results to fruition', with the phases treated in an iterative manner rather than a sequential manner, responding to the specific context emerging (Hirsch Hadorn et al., 2008; Hirsch Hadorn et al., 2006; Pohl and Hirsch Hadorn, 2008). A few years later, three German scholars also described transdisciplinarity as a research '*approach*' (rather than a method), working in three phases: 'formation of a common research object'; 'production of new knowledge (interdisciplinary)'; and 'transdisciplinary integration: contributing to societal and scientific

progress'. In the graphic presentation of their approach, they stress the double ambition of creating both societal results and scientific results (Jahn et al., 2012). In the same year, a larger international team of authors (including one author of the Jahn et al., 2012 article) describes transdisciplinarity in almost the same manner, with basically the same graphic, but replacing the names of the three phases with: 'A: problem framing & team building'; 'B: Co-creation of solution-oriented and transferable knowledge'; and 'C: (Re-) integrating and applying the co-created knowledge' (Lang et al., 2012). See all four transdisciplinary process descriptions in Table 3.1.

The common transdisciplinary approach coming from all four proposals in Table 3.1 can be seen as a flexible iterative approach to elementary steps, which is required to allow for the unexpected. This is essential when alternative knowledge sources and the perspectives of multiple stakeholder groups, with their own specific needs and experiences, are intended to be equally represented in the process of knowledge creation. What is missing in all four proposals in Table 3.1 is a phase for the generation of a collective and shared questioning of the situation at hand and development of the research approach, including the iterative nature of research: an initial step to define the strategic research focus of a transdisciplinary research project based on a research portfolio and vision of transdisciplinary researcher or a transdisciplinary institute, and a final step to provide feedback on the outcomes of the transdisciplinary research project in light of the research portfolio of the transdisciplinary researcher or transdisciplinary institute. Both are defined in Table 3.1 as step 1 and 6.

The multidisciplinary perspective of transdisciplinary research has resulted in several methodological considerations and tools being lent from different social sciences approaches. The approaches described in the transdisciplinary literature have in this sense a very strong resemblance to other related fields that search for contributions to societal challenges by applying comparable transdisciplinary principles. For example, the methodological considerations in the field of participatory policy making are similar to transdisciplinary research: see Table 3.2. Friend and Hickling (2005) described their consensus building process as a 'twin track' or U-loop process, engaging in both a political work process and a technical–scientific work process, describing main steps as 'shaping', designing', 'comparing' and 'choosing'. Susskind et al. (1999), in their *Consensus Building Handbook*, described it comparably with three 'zones': a 'divergent zone'; a 'groaning zone'; and a 'convergent zone'. Comparable approaches can be found in the field of collaborative policy making (Chambers, 2002; Kaner, 2011), with a large availability of evaluations, critical reviews and discourse on effectiveness, legitimacy, implications for education and the capacity to catalyse transformations (Elle et al., 2002; Vermeulen et al., 1997; van der Waals and Vermeulen, 2002).

Seemingly comparable approaches that contribute to sustainable development related research, in various disciplines, developed similar procedural approaches as what we have described for sustainability science, but they are not always labelled with the same concepts. Nevertheless, there has been cross-pollination between these disciplines.

Table 3.1 Chronological synthesis of transdisciplinary research project planning in the field of sustainability sciences

Transdisciplinary research process steps	*Scholz et al. (2006) Transdisciplinary case study methodology*		*Hirsch Hadorn et al. (2008) Transdisciplinary approach*	*Jahn et al. (2012) Transdisciplinary conceptual model*	*Lang et al. (2012) Ideal–typical transdisciplinary research process*
6 steps *Within broader research portfolio; linked to research vision; strategic focus; iterative process*	*5 steps* *Two directions of working*		*3 phases* *Iterative rather than sequential*	*3 phases* *Parallel*	*3 phases* *Continuous evaluation; strengthen participation; mitigate conflict*
	Forward operating	*Backward planning*			
1) Research vision and strategy					
2) Problem exploration and structuring	1) Goal specification	10) Case faceting	Problem identification and structuring	Formation of a common research object	A) Problem framing & team building
3) System understanding	2) System analysis	9) Characteristics of systems model		Production of new knowledge (interdisciplinary)	B) Co-creation of solution-oriented and transferable knowledge
4) Search and compare solutions	3) Scenario construction	8) Characteristics of scenarios	Problem analysis		
	4) Multi-criteria assessment	7) Assessment criteria and procedure		TD integration: contributing to societal and scientific progress	C) Re-integrating and applying the co-created knowledge
5) Choose, decide and prepare for application	5) Generation of action orientations	6) Goal formulation	Bringing results to fruition		
6) Synthesize and feedback with overall vision and strategy					

Table 3.2 Transdisciplinary research project planning in the field of participatory policy making according to the transdisciplinary research process steps in the field of sustainability sciences

Transdisciplinary research process steps	*Friend and Hickling (2005) Process of strategic choice*	*Susskind et al. (1999) Consensus building*	*Vermeulen et al. (1997), van der Waals and Vermeulen (2002)*	
1) Research vision and strategy		Start up Convening	Political formalizing	
		Go/no-go	Choosing internal or dialogue	
2) Problem exploration and structuring		Clarifying responsibilities, process design	Problem structuring	
			Process management	
3) System understanding	Shaping	Consensus building	Weighing in dialogue and confrontation	Perceptions exchange
	Designing			Generating solutions
4) Search and compare solutions	Comparing	Deliberating		Analyze options
				Collaborate weighing
	Choosing	Deciding		Consensus creation
5) Choose, decide and prepare for application			Feedback	
			External communication	
6) Synthesis and feedback with overall vision and strategy		Implementing		
	Organizing learning and development			

All the schools of research highlighted in Tables 3.1 and 3.2 are developing methods and tools for the six main steps in the transdisciplinary process. This opens the floor for various challenges when executing transdisciplinary research – the challenges of:

- Dealing with how various disciplines perceive the joint problem-solving research: the diversity of methods applied; and the mutual exchangeability of these methods;
- Dealing with challenges in connecting the various forms of knowledge and information and best ways for working towards a shared perception of problems and suitable solutions;
- Dealing with the requirements of scientific quality (validity, reliability, generalizability, traceability and more);
- Dealing with the best ways of enabling communication between a wide variety of stakeholders;
- Dealing with uncertainty about the key success factors for application of the results of such a research process;
- And, last but not least, how, for the academic researchers in their various disciplines, they can create new roles, while still being awarded in the (traditional) academic system.

Apart from these challenges, in the research process itself various disciplines are dealing with some of the same crosscutting challenges, which need to be addressed at the institutional level and within the respective disciplines. Researchers need to deal with ethical issues about stakeholder engagement, fairly dealing with competing interests and conflict of interests as well as with promises made. Transdisciplinary research institutes need to consider how their application of the transdisciplinary research results can be ensured, what forms of involvement on the part of policy makers or other decision-makers can be applied and how the intended changes can be achieved. Transdisciplinary research also has implications for academic teaching, in terms of teaching curriculum, aiming at skills development. It needs to have a strategy in order for (PhD) student projects to be integrated into transdisciplinary research projects, simultaneously ensuring applicable outcomes and fruitful student experience and graduation. Transdisciplinary research institutes need to be prepared to respond to research funding agencies as these are in various ways demanding transdisciplinary research, but not always in line with the expectations of the proponents of the three 'tastes' of transdisciplinarity described in Chapter 2. Such challenges, and many more, will have to be addressed when working with the diverse communities of practice in various disciplines while contributing to the field of sustainable development.

In the next section, we will have a closer look at a transdisciplinarity toolbox, identifying the main principles of transdisciplinary research and suggested types of tools and methods that can be applied for stakeholder engagement, dealing with multiple perceptions, worldviews and value systems, collective ideation, selection and choice making.

3.4 The basic methodological principles of transdisciplinary research

Transdisciplinary research varies from one-person projects (e.g. PhD projects; small research projects) to very complex projects, implying challenges in how to develop and design these projects. As can be seen from Tables 3.1 and 3.2, transdisciplinary research projects are projects with many stakeholders, making them very different from individual research projects that cover the proposed six transdisciplinary research project steps. This has methodological implications for the overall research design and addressing the many actors in different project designs, as well as for the art and type of activities contributing to the transdisciplinary research – especially activities for the collaboration between academic and non-academic actors that contribute to the exchange, collection, joint analysis and synthesis of knowledge.

These activities should enable more flexible and open work, instead of strict protocols and objective validity-based research, as is the case with 'mode 1' knowledge creation. At least eight essential principles of transdisciplinary research can be identified: 1) abductive reasoning; 2) open-minded multi-actor reflection; 3) iterativeness; 4) triple focus; 5) understanding the bigger picture; 6) multi-level learning; 7) long-term and full system perspective; and 8) an orchestrated approach. The combination of these principles illustrates transdisciplinary research's different approach to scientific inference compared to traditional 'mode 1' knowledge production.

3.4.1 Abductive reasoning

Scientific inference within transdisciplinary research is based on abductive reasoning, as the process of reinterpretation and recontextualization throughout the research process (Eastwood et al., 2016). Modell (2009) clarifies that

> abduction does not move directly from empirical observations to theoretical inferences, as is the case in purely inductive research, but relies heavily on theories as mediators for deriving explanations . . . while preserving researchers' sensitivity to variations in situated meanings.
>
> (Modell, 2009, p. 209)

Theories are therefore used in a continuous process of enhancing the understanding of the situation at hand by moving from empirical observations to theoretical inferences, guided by the hunch of the researcher or actors involved in the transdisciplinary research process. The transdisciplinary research process, therefore, uses prior knowledge from academics as well as non-academics: knowledge of how societies work through the thorough process of scientific research as well as through the learning processes of individuals or groups of individuals by being exposed to and embedded in practice. While emergent knowledge creation forms the basis for hypothetic-deductive theory testing (Eastwood et al., 2016),

transdisciplinary research – in order to create collective knowledge of and actively contribute to urgent societal challenges – is constituted by a process of intuitive pre-knowledge on the situation (i.e. the hunch). This knowledge is available in the social practice itself and is shared by different stakeholders in a knowledge creation process by feed-backing between practice and theory, called abductive reasoning (Witjes, 2017). In social sciences, especially in critical realism, the abductive research strategy is explicitly linked to the grounded theory approach (Reichertz, 2009) and is used in order to construct theories that are grounded in everyday activities, in the language and meanings of social actors in the field of study (Ong, 2012). This makes it especially useful for transdisciplinary practices.

3.4.2 Open-minded, multi-actor reflection

Abductive reasoning for an enhanced system understanding of the societal challenge at hand is needed for academic and non-academic actors to share and enhance understanding by collective reflection. The outcomes of these collective reflections lead to adjusted behavioural actions and solutions to societal challenges. In order to get academic and non-academic actors involved in this multi-actor reflection process, they have to be taken out of their comfort zone and routines: logical inference for all actors means critically reflecting on day-to-day situations that contribute to the societal challenge as object of study of the transdisciplinary research process. This also counts for the academic actors involved: they have to be willing and able to see through disciplinary and methodological boundaries while aiming for meaningful outcomes for practice and science alike.

3.4.3 Iterativeness

For all actors, being involved in critically reflecting on the societal challenge requires letting go of inert concepts, observations or social roles. The latter could mean that different actors will be involved in the process of contributing to the understanding of the challenge by giving a different perspective. The iterativeness and pragmatic stance of a transdisciplinary research process and the continuous search for the unknown also mean the social roles or even the actors themselves may not be seen as stable throughout the entire process. It is, therefore, a shared responsibility for all actors involved to critically reflect on the transdisciplinary research process as well as on the outcomes, making higher order learning a key feature of transdisciplinary research. Sharing individual critical reflections on the research outcomes as well as on the process itself in a multi-actor setting, enhances the transformative capacity of a transdisciplinary research project. As a consequence, a strict linear research project, as common in ‘mode 1’, is not possible; during the project, one needs to enable return to earlier steps as a result of reinterpretations and new insights, as suggested by many scholars (see also Table 3.1).

3.4.4 The triple focus

The importance of the collective reflection process with academic and non-academic actors is based on their pluriversal knowledge (i.e. 'a world of [knowledge] where many worlds fit'; Escobar, 2018), meaning an acknowledgement that each world of knowledge is represented by the knowledge of a specific actor on the challenge at hand. The process of reflection on this pluriversal knowledge, while at the same time acknowledging each actor, forces a transdisciplinary researcher into the double role of facilitating and coordinating the transdisciplinary research process as well as creating successful situations in which the academic and non-academic actors can exchange their knowledge and experience. This underlines that a dual focus on the methods applied to ensure transdisciplinary research (as addressed in this chapter) and on the type of theoretical and practical knowledge needed to address the challenge at hand is needed for the quality of a transdisciplinary research. Moreover, the contribution to societal challenges also implies the development of new ideas for possible interventions that can be implemented by having the right strategic decisions makers among the academic and non-academic actors on the team. Consequently, research aiming at contributing to societal challenges requires academics and their institutions to take active part in enabling such societal contribution by 1) leading the process (i.e. methodologically); 2) bringing together the right actors with the right knowledge (i.e. theoretically); and 3) ensuring the meaningfulness of the research outcomes (i.e. the implementation of the interventions). An overall transdisciplinary research strategy has therefore a *triple focus* on content, process and implementation: the contribution to meaningful outcomes for practice (i.e. an active contribution to the societal challenge) and for science (i.e. a contribution to debates in literature on the content of the research) and a well-developed, resilient research plan, including methodological and tool considerations to get to the meaningful outcomes.

3.4.5 Understanding the bigger picture

Academics leading a transdisciplinary research project should be able to face the complexity and wickedness of societal challenges: they have to be used to stepping out to practice and getting their boots dirty in seeking to achieve a higher understanding of practice. The three main ambitions of complex system knowledge integration, addressing the persistency of wicked societal problems and empowerment in light of urgent transformational challenges (see Figure 2.4.) in the playing field of transdisciplinary research can therefore be seen as basic principles to ensure successful coordination of a transdisciplinary research process and, moreover, meaningful outcomes of the research for practice and science (as addressed by Lang et al., 2012). Transdisciplinary research methodology should be able to understand the bigger picture by applying systems thinking to ferret out the challenge at hand, while ensuring multi-actor collaboration in reflecting on pluriversal knowledge. The dirty-boots mentality helps transdisciplinary researchers with maintaining the bigger picture while ensuring project details, but will also ensure close contact with the different actors involved in the project.

3.4.6 Multi-level learning

As already explained in Figure 3.1, the feedback between the different transdisciplinary research levels also counts outside of the transdisciplinary research project, at the transdisciplinary project portfolio and transdisciplinary research institute level. Multi-level learning as part of a transdisciplinary research project (i.e. individual actor, collective reflection, overall reflection on content and process) forces transdisciplinary research to use knowledge sources from multiple actors to feed their knowledge of the system, of which the challenge is part of leading to an implementable outcome. It is in the process of multi-level learning that a higher understanding of the challenge and related solutions are able to ensure the meaningfulness of the outcomes of a transdisciplinary research process for both practice and science.

3.4.7 The long-term and full system perspective

Outcome-oriented ambitions should be accompanied by a continuous reflection on whether the transdisciplinary research process contributes to the understanding of a complex and wicked problem or just leads to practical, or sometimes consultancy, advice, to single actors that form part of the system of the challenge. This means that transdisciplinary research always has a long-term and full system perspective and that the outcomes should be pointed at long-term visions that contribute to a more sustainable society (see also Figure 2.4).

3.4.8 The orchestrated approach

Depending on the complexity and wickedness, but also on the urgency or development of the challenge at hand throughout the project, the transdisciplinary researcher should choose between orchestrated and pragmatic approaches to ensure collective reflectivity on the pluriversal knowledge of the challenge (Popa et al., 2015). The pragmatic approach is mainly for smaller projects, in scope, complexity and time, and therefore has questionable contribution to the development of a more sustainable society. The orchestrated approach is for projects of greater scope but can also be in need of smaller pragmatic process elements.

3.5 Transdisciplinary research tools

Serving the high expectations and challenges for transdisciplinary research methods, many tools have been developed and applied in transdisciplinary research to ensure meaningful outcomes for practice and science. Recently, several transdisciplinary scholars have critically analyzed their research with a methodological focus and shared their experiences with the application of several methods and tools. In Table 3.3, the experiences of four renowned transdisciplinary scholars are grouped according the transdisciplinary process steps, as presented in section 3.2.

Table 3.3 Transdisciplinary methods and tools in different literature

Transdisciplinary research process steps	*Bammer (2015)*	*Fahy and Rau (2013)*	*Franklin and Blyton (2013)*	*Byrne et al. (2017)*
1) Research vision and strategy	*Toolkit #6* Research integration and implementation	*Chapter 5* Sustainable development of what? *Chapter 6* Indicators of society-nature interaction	*Chapter 2* Developing and delivering social science research for sustainability	*Chapter 3* Sustainability as contingent balance between opposing though interdependent tendencies: a process approach to progress and evolution
2) Problem exploration and structuring	*Toolkit #2* Engaging and influencing policy *Toolkit #1* Co-producing knowledge *Toolkit #4* collaboration *Toolkit #3* Dialogue methods for knowledge synthesis	*Chapter 3* Social groups and collective decision-making: focus group approaches *Chapter 2* Disciplinary methods challenge	*Part II* Approaches to sustainability research	*Part 2* Transdisciplinary conversations and conceptions
3) System understanding	*Toolkit #7* (Dynamic) systems thinking *Toolkit #8* Integration methods	*Chapter 4* Local lives and conflict: towards a methodology of dialogic research	*Part III* Disseminating sustainability research	
4) Search and compare solutions	*Toolkit #5* Change	*Chapter 7* Mapping for sustainability		
5) Choose, decide and prepare for application		*Chapter 6* Indicators of society–nature interaction	*Chapter 2* Developing and delivering social science research for sustainability	
6) Synthesis and feedback with overall vision and strategy	*Toolkit #2* Engaging and Influencing policy *Toolkit #6* Research integration and implementation	*Chapter 5* Sustainable Development of what?		

Bammer, from Australia National University, summarized her methodological reflections in the *Toolkits for Transdisciplinarity* series (Bammer, 2015). Published between 2015 and 2017 in *Gaia*, she highlights existing compilations of methods useful for transdisciplinary research. The toolkits unite several existing tools from other methodological research fields and range from full range transdisciplinarity, via a collaborative focus, to tools to synthesize disciplinary knowledge, apply systems thinking and support change.

Fahy and Rau from the National University of Ireland share experiences with different transdisciplinary research projects in a critical review of methodological approaches, as well as tools for the integrated investigation of sustainability questions (Fahy and Rau, 2013). They discuss methodologies based on their experiences with transdisciplinary research on attitudes and behaviour observable at the local level – from families and households to individual organizations within communities – and focus on comparative sustainability research across different levels of socio-political organization, from cities and regions to nation-states.

Franklin and Blyton from Coventry University recollected their transdisciplinary experiences specifically related to the BRASS project (Franklin and Blyton, 2013): a large-scale, ESRC-funded project on community sustainability. Their book contains the illustrated methods and approaches applied in this transdisciplinary research project to disseminate findings, influence policy, and communicate with non-academic actors as well as work with the media.

Byrne, Mullally and Sage from the University College of Cork summarize their reflections on transdisciplinary methodology and tools based on their research (i.e. Sustainability in Society Initiative) and related to the Transdisciplinary Conversations conference they organized in 2013. Their book (Byrne et al., 2017) demonstrates how they were able to make progress in contributing to a more sustainable world by applying transdisciplinary research methods. The book includes several examples.

Focusing on the transdisciplinary process steps, we can conclude that steps 2–5 are covered in the reflections of all the mentioned transdisciplinary scholars. Some even handle methods and tools for steps 1 and 6, but these methods and tools are not included in the empirical examples given: experiences on separate transdisciplinary research projects are shared, but not on a transdisciplinary researcher or transdisciplinary institute level, emphasizing the attention for strategy and vision development for transdisciplinary research.

3.6 Considerations for the application of transdisciplinary approaches, methodological principles and tools

Sustainability research requires not only natural sciences knowledge of the environmental system, but also expertise in technical and social sciences, in order to contribute to societal changes. As a result, research projects require not only development and integration of academic and non-academic expert knowledge in a collaborative way; public outreach and societal engagement also need to be undertaken to enable a direct contribution to societal developments. Consequently,

transdisciplinary research entails the challenge of engaging with different actors, each with their own stake in the research process and its outcomes, and having to deal with multiple perceptions, worldviews and value systems, collective ideation, selection and choice making. These challenges need to be considered and overcome through strategies throughout the transdisciplinary research process. Gaziulusoy et al. (2016) summarize the challenges transdisciplinary researchers face in three types:

1 *Inherent challenges*: challenges that arise directly from the characteristics inherent to transdisciplinary research, like abductive reasoning, iterativeness and dual focus, as mentioned in section 3.3;
2 *Institutional challenges*: challenges that arise from the current structures and procedures of knowledge generation and performance evaluation in academic institution. Challenges come from institutions that are more used to 'mode 1' knowledge creation and have to get used to other modes as well;
3 *Teamwork challenges*: challenges that stem from the requirement of collaboration between researchers from backgrounds with different expertise and who are often from different academic institutions as well as reflection with non-academic actors in ways to enable mode 2 and 3 knowledge generation.

Whereas inherent and teamwork challenges have been addressed in this chapter, institutional challenges depend on the characteristics of the different institutions. To start the process of transdisciplinary research and at the end ensure that the developed interventions are applied, working from traditional institutions, as universities mostly are, is not easy. Transdisciplinary researchers have to learn to be smart in working with the available resources, for example, linking several smaller projects with a similar and comparable way of working towards an overall research programme (Bootsma et al., 2014; Gaziulusoy et al., 2016). By building up transdisciplinary research step-by-step transdisciplinary researchers aim for a transdisciplinary research portfolio or even smaller or bigger institutes that have an enhanced impact in society. This model of transdisciplinary research growth is inherent to the growth of the knowledge generated and interventions developed and, therefore, is inherent to the learning process transdisciplinary research implies. The collaboration and co-designing process between academic and non-academic actors is crucial to ensuring constant growth, leading to enhanced contribution to societal transitions (Moser, 2016).

The combination of the inherent, institutional and teamwork challenges puts high demands on transdisciplinary researchers and their capacities, for example to be constantly able to get key decision-makers linked to the research process, while addressing conflicting interests between actors can even demand the transdisciplinary researcher take a mediating role (Susskind et al., 1999). In all cases, the transdisciplinary researcher has to ensure that the different principles (as discussed in section 3.3) and concurrent transdisciplinary research activities are consistently reflected by the basic philosophy of collaborative understanding and intervention. The transdisciplinary researcher needs to bring along a sense of the legitimacy,

relevance and representativeness (see step 4 of the transdisciplinary research project) of the transdisciplinary research project outcomes as it develops. This makes the salience of transdisciplinary research that aims at the development of knowledge and interventions linked to the problem or societal challenge at hand more important than the curiosity for developing this knowledge or intervention. Consequently, the playing field of transdisciplinary research in sustainability sciences comes with the three main ambitions, as mentioned in Figure 2.4: challenges of pluralistic scientific knowledge creation, features of societal problems and the urgency of major persistent challenges.

The multi-level characteristic of transdisciplinary research (i.e. project, portfolio and institution) also brings along considerations on different levels of learning from transdisciplinary research outcomes: individual project learnings, multiple project learnings and learnings on the contribution of the institute to societal challenges. The academic institute is therefore also confronted with the implementation of these learnings in their teaching activities. Integrating educational activities in transdisciplinary research opens up the possibility of developing future capacities for transdisciplinary research and making young researchers aware of societal challenges and their implications.

The six-step model presented in this chapter supports transdisciplinary research in working from an overall transdisciplinary research architecture, including strategic questioning at multiple levels (i.e. project, portfolio and institute) that connects the vision of the academic institution regarding its contribution to societal challenges to the specific projects and creates a flexible iterative approach to elementary steps, which is required to allow for the unexpected. Consequently, the responsibility for transdisciplinary research goes beyond the capacity of a single transdisciplinary research(er) and should be covered by a group of transdisciplinary researchers working within a transdisciplinary research institute that collectively contributes to meet societal sustainability challenges.

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