Chapter 10: Transdisciplinarity in environmental sociological research

Overview

In this chapter, you will find out more about the relationship between environmental research, society, and politics. You will learn about different concepts and understandings of science that characterise problem-oriented research in the environmental field. We will focus primarily on the research principle of transdisciplinarity, which is based on integrating the knowledge of different scientific disciplines and non-scientific actors. You will develop an understanding of the challenges, strengths and weaknesses of problem-oriented, transdisciplinary research.

Socio-ecological crises and socio-technical transformation processes pose major challenges for our societies. They make it necessary to a) translate scientific findings about causes, drivers and solutions into societal problem-solving strategies, and b) align scientific knowledge processes with societal needs and demands. This kind of translation forms the core of transdisciplinary research – it is highly complex and challenging, and does not somehow occur automatically, as will be shown below.

The various subsystems within a society, such as science, economy, politics, law, civil society and mass media, all mutually influence one another (Luhmann 2012 [1984]). Society and everyday life are increasingly influenced by science ("scientification of society"), but society also places demands on science and calls for innovations and solutions to problems ("politicisation of science") (Weingart 1999a). Various authors assume that the interpenetration between science and society is increasing. This is initially an empirical question, the answer to which is highly controversial (Weingart 1999b). In addition, some of these authors go further and suggest that this increasing interpenetration between science and society has led to a normative demand that scientific systems must, at least in part, adapt to these new conditions. This demand is usually made against the background of intensifying socio-ecological crises such as anthropogenic climate change.

The concept of transdisciplinarity describes both the diagnosis of the shift taking place in science and a normative project of adaptation to changing problems that is considered necessary. Here is a general definition that encompasses both the normative and diagnostic aspects of the concept of transdisciplinarity: Transdisciplinarity describes a form of research in which the focus is on dealing with concrete social problems (problem orientation) and which is carried out cooperatively between different scientific disciplines (interdisciplinary orientation) and with the involvement of non-scientific actors (transacademic orientation) (see, for example, Hirsch Hadorn et al. 2008). The term transdisciplinarity thus denotes a research principle (and not a method or methodology) that goes hand in hand with a specific organisational form of science (Becker & Jahn 2006: 320). In transdisciplinary research, the focus is always on concrete societal (i.e., real-world) problems. Transdisciplinary research can be understood as a reaction to the progressive fragmentation and specialisation of the scientific system, which is increasingly at odds with complex, systemic problems that transcend disciplinary boundaries (e.g., anthropogenic climate change or microplastics in the world's oceans), as well as to the growing social demand for scientific expertise in solving real-world problems. There are two different understandings of transdisciplinarity. Although they both fundamentally agree that transdisciplinarity refers to the collaboration between different scientific disciplines to tackle real-world problems, they differ with regard to their view of the relationship between science and society. One understanding sees transdisciplinarity as a purely internal scientific principle (Mittelstrass 2018), which aims to overcome disciplinary boundaries and integrate disciplinary paradigms. The other emphasises the necessity of involving non-academic actors in the research process in order to generate socially robust knowledge (see in particular Gibbons et al. 1994 and Nowotny et al. 2001). The latter understanding of transdisciplinarity as cooperation between academic and non-academic actors is more widespread today and also forms the basis of this chapter.

In the following section we will look at the origins of the concept of transdisciplinarity, which date back to the 1970s, and briefly outline the relevant debates from that decade, as the topics of those debates have continued to come up in subsequent debates on transdisciplinarity ever since. We will then introduce the concepts of *Mode 2* and *post-normal science*, which laid the foundation for the dominant understanding of transdisciplinary research in the 1990s. This understanding of transdisciplinarity has been taken up by social ecology and concretised in an application-oriented way to become the discipline's guiding research principle. We have therefore devoted one section of this chapter to social ecology. Finally, we will present the concept of transformative science, which builds on the established understanding of transdisciplinarity, but claims to go beyond it.

1. The origins of the concept of transdisciplinarity

The term transdisciplinarity first came to prominence in 1970 at a meeting of the Organisation for Economic Co-operation and Development (OECD) in Paris on the subject of interdisciplinarity. The creation of the term is usually attributed to Jean Piaget, a prominent Swiss psychologist (Bernstein 2015). At this conference, Piaget advocated an understanding of transdisciplinarity in which transdisciplinarity is characterised by a higher degree of integration of scientific knowledge from different disciplines than is the case with interdisciplinarity. In transdisciplinary research contexts, the boundaries between scientific disciplines become blurred or even dissolved, and a kind of holistic unified science can emerge. In Piaget's words: “Finally, we may hope to see a higher stage succeeding the stage of interdisciplinary relationships. This would be, ‘transdisciplinarity’, which would not only cover interactions or reciprocities between specialised research projects, but would place these relationships within a total system without any firm boundaries between disciplines” (Piaget 1972: 138).

Following on from Piaget, in the 1970s the systems scientist Erich Jantsch, a co-founder of the Club of Rome, developed his own concept of transdisciplinarity as a normative organisational principle for universities that explicitly takes into account the value-based nature and social embedding of science so that universities can contribute to solving the major challenges facing humanity (Jantsch 1970). Jantsch's concept is also based on the idea of a unity of the sciences. He aimed to overcome the disciplinary fragmentation and specialisation of the sciences by having universities establish cooperative and coordinated structures in teaching and research that transcend disciplinary boundaries. This should ultimately lead to a synthesis of different disciplinary epistemologies, whereby interdisciplinary theories and concepts can emerge (Jantsch 1970: 412). Linked to this is Jantsch's normative claim that universities should contribute to "social renewal": "Essential is only that inter- and transdisciplinary organization and coordination of science are necessary for education and innovation to follow the purpose of society's self-renewal" (Jantsch 1970: 416). To this end, the entire university system should be structured in such a way that disciplinary boundaries are dissolved. For Jantsch, transdisciplinarity is thus: "The coordination of all disciplines and interdisciplines in the education/innovation system on the basis of a generalised axiomatics (introduced from the purposive level) and an emerging epistemological pattern" (Jantsch 1970: 411). In comparison to Piaget, whose concept of transdisciplinarity refers to an extended form of interdisciplinarity (a kind of "discipline-less interdisciplinarity"), Jantsch also associates transdisciplinarity with a normative organisational principle for universities and the associated claim that science should become a social problem solver.

Almost at the same time as Piaget and Jantsch, the German philosophers and sociologists Gernot Böhme, Wolfgang van den Daele and Wolfgang Krohn formulated the thesis of the "finalisation of science" (Böhme et al. 1976), which is interpreted by some as anticipating the sociological debate on transdisciplinarity that took place in the 1990s (Weingart 1997). They understand finalisation to mean that objectives which are external to science – political, economic or social – are increasingly becoming the driver of scientific development and scientific progress. In the process, social needs and scientific interests are increasingly linked, which means that science is increasingly judged from a perspective of usefulness. While Jantsch explicitly makes the normative claim that science should benefit society and can best do this in the transdisciplinary form of organisation, Böhme, van den Daele and Krohn critically point out with their finalisation thesis that a science that submits to objectives that are external to science runs the risk of becoming a tool for stabilising power.

In the contributions from the 1970s that explicitly refer to transdisciplinarity (Jantsch and Piaget) or that refer to it in retrospect (Böhme, van den Daele and Krohn), one can find the key points that characterised later debates about the concept of transdisciplinarity: a) the normative claim that transdisciplinary research is necessary in order to tackle societal challenges, b) the orientation of transdisciplinary research towards dealing with real-world problems, and c) the idea that interdisciplinarity and the associated challenge of knowledge integration is an important characteristic of transdisciplinarity. The integration of non-academic partners that is relevant to today's dominant understanding of transdisciplinarity was not yet associated with transdisciplinarity at that time. This developmental step in the understanding of transdisciplinarity did not occur until roughly two decades later, as will be described in more detail in the following section.

2. New forms of knowledge production: Mode 2 and post-normal science as conceptual foundations of transdisciplinarity

After the topic of transdisciplinarity received less attention in the 1980s, scientific debates intensified again in the 1990s following the development of the concepts Mode 2 (Gibbons et al. 1994) and post-normal science (Funtowicz & Ravetz 1992, 1993). For many decades, a mode of knowledge production was taken for granted and undisputed in the scientific world, in which research questions were posed in a disciplinary manner and dealt with according to academic quality criteria. In this mode, societal "problems" or challenges were only incorporated in an unsystematic way. Environmental research was also dominated by scientific approaches that drew their legitimisation from internal scientific discourses and stopped at disciplinary boundaries. In the 1990s, this traditional understanding of science was criticised as "academic", "one-dimensional" and "incomplete" and confronted with alternative models of interdisciplinary and problem-oriented knowledge production in order to scientifically address the urgent future issues that are neglected within the traditional model. These alternative models are known as Mode 2 science and post-normal science. While the Mode 2 concept explicitly refers to transdisciplinarity, post-normal science is more implicitly associated with transdisciplinarity. However, both approaches have contributed significantly to sharpening the conceptual contours of the notion of transdisciplinarity and to initiating new debates.

2.1. Mode 2

In their 1994 book "The new production of knowledge. The dynamics of science and research in contemporary societies", the authors Michael Gibbons, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott and Martin Trow outline the contours of a new mode of knowledge production from the perspective of scientific theory and sociology. They call it Mode 2 in order to clearly differentiate it from the classic form of basic research (Mode 1). Gibbons et al. (1994) describe a shift in knowledge production away from an extra-societal, purely university-based production of "abstract truths" and towards the development of problem-oriented analyses and solution approaches that are related to real-world practices and embedded in specific contexts, and in which a large number of scientific and non-scientific actors are involved. The hitherto internal scientific quality criteria for assessing the quality of knowledge production remain necessary, but are no longer sufficient for lending validity to scientific knowledge. The fundamental argument that Nowotny, Scott and Gibbons set out in their 2001 work "Re-thinking science. Knowledge and the public in an age of uncertainty" (partly in response to the criticism they received) can be summarised briefly as follows: In contrast to Niklas Luhmann's ideas about a progressively functional differentiation of science, society, politics and the economy, modern societies are experiencing an ever-increasing interpenetration and thus a "de-differentiation" or merging of science and society. On the one hand, scientific knowledge is playing a key role in more and more areas of life. For example, the scientification of nutrition can be observed in popular scientific self-help books. On the other hand, modern societies are increasingly confronted with the negative consequences of scientific and technological progress, which they in turn try to deal with by using science. This is also linked to the fact that society is making increasing demands on science with regard to its usefulness. This argument could already be found in the finalisation thesis presented above and in Jantsch's work. The de-differentiation of science and society has created a new mode of knowledge production (Mode 2), which exists alongside the classic form of knowledge production, i.e., basic research (Mode 1), and is becoming increasingly important. According to Nowotny, Scott and Gibbons, the core element of this new mode of knowledge production is transdisciplinarity as a research principle. Table 3 compares Mode 1 and Mode 2 of knowledge production and illustrates the understanding of transdisciplinarity associated with Mode 2.

Table 3: Comparison of Mode 1 and Mode 2; source: own illustration based on Gibbons et al. (1994: 3), Gibbons (2000: 159f.), Nowotny et al. (2001: 186ff.) and Coghlan (2014: 541)

	Mode 1	**Mode 2**
Problem identification	Disciplinary problem formulation; research oriented towards internal scientific interests	Contextualised, i.e., multi-perspective problem formulation; research oriented towards real-world problems
Actors involved in the research process	Homogeneity: scientists from institutions that conduct basic research	Heterogeneity: scientists within and outside universities, as well as non-academic actors
Organisation of the research process	Hierarchical and stable	Heterarchical and dynamic (project-based)
Quality control	Control system within a scientific discipline	Heterogeneous control system

In the basic research mode (Mode 1), research problems and questions are identified and formulated within the framework of academic disciplines and driven by an interest in scientific knowledge. Each scientific discipline works on problems that arise from gaps in the current state of research within that discipline: It answers scientific questions. In contrast, in Mode 2 problems are identified and formulated by taking into account multiple perspectives. Here, internal scientific and disciplinary interests are not the sole yardstick for assessing the relevance of research problems; societal interests also play a role. Accordingly, science in Mode 2 focuses on dealing with real-world problems, such as those connected with the effects of socio-ecological crises (e.g., biodiversity loss, microplastics in the oceans, scarcity of raw materials) (Gibbons et al. 1994: 4).

While the actors involved in the research process in Mode 1 form a largely homogeneous group of university-based academics, Mode 2 is characterised by greater heterogeneity. In addition to academics from universities, Mode 2 research processes also involve actors from non-university research and development (e.g., from applied research institutions or R&D departments within companies) and practitioners (e.g., experts from associations, authorities, consultancies or think tanks). While universities are the central players in Mode 1 research, they do not dominate in Mode 2. The shift towards a knowledge society has not only led to society becoming increasingly science-driven, but also to the distribution of research-relevant knowledge far beyond the field of science (Nowotny et al. 2001: 89). Furthermore, Mode 2 research only becomes practically relevant if non-university actors participate in the research process.

The group of actors involved in the research process is primarily related to the organisation of the research process. In Mode 1, the way the research is organised is determined by the hierarchical structure of universities and research institutions, which gives it a certain stability but also rigidity. Research in Mode 2 is organised more heterarchically and dynamically. This means that the research is project-based and takes place in more or less loose networks of heterogeneous players and often without clear or fixed hierarchies. The necessity of project-based work arises primarily from the heterogeneity of the actors involved, who belong to different organisations.

The two modes of knowledge production also differ in terms of quality control. Quality control refers to the evaluation and assessment criteria used to judge the quality of research results. In Mode 1, quality control primarily takes place within the boundaries of scientific disciplines. The assessment of what is considered "good science" follows subject-specific standards. The peers who evaluate and criticise scientific findings and ideas are mainly recruited from the scientific community. Quality control thus takes place within a narrow and clearly defined internal scientific group. In Mode 2 on the other hand, the group of peers is larger and the quality standards are more diverse. Since a large number of heterogeneous actors are involved in the research process and research problems are identified from multiple perspectives, it is no longer possible to clearly determine who can assess the quality of the research results and which standards they can use. In addition, given that Mode 2 is a socially situated form of knowledge production, researchers are not only accountable to their peers (as in Mode 1), but also to the social actors who are part of the research process and in whose environments the positive and negative consequences of the research results are felt. The evaluation of research results is therefore no longer carried out solely on the basis of (disciplinary) scientific standards. Instead, research must also be measured against assessment criteria such as usefulness, dangerousness, desirability, etc., which are used by non-academic stakeholders from politics, business, civil society, and the citizenry, etc. This entails a much more heterogeneous and comprehensive system of quality control.

As the description of the characteristics of Mode 2 suggests, a separation of science and society no longer exists in this form of knowledge production. Science and society are engaged in a mutual exchange and are inextricably interwoven (Latour 1998). They develop in a co-evolutionary way. In Mode 1, if science addresses society at all it is by providing fundamental findings that are taken up and made applicable by companies, political decision-makers, and authorities, etc. However, society now also speaks to science by participating in the identification of research problems. Accordingly, it is not only science that changes society, but also society that changes science. The result is a "context-sensitive" science that produces "socially robust knowledge", i.e., knowledge that is also widely recognised and valid outside the scientific system (Gibbons 1999: C82, 2000: 161). Gibbons et al. consider the risk of such knowledge being doubted or rejected in the context of social debates to be far lower than in the case of knowledge that has been generated in a purely internal scientific research process and subjected to quality control merely within scientific disciplines.

All in all, Mode 2 of knowledge production is based on a changed relationship between science and society (keyword: de-differentiation), which primarily affects which research questions (keyword: problem orientation) scientists work on in collaboration with whom (keyword: transdisciplinarity). What remains open is whether Mode 2 merely represents a sociological diagnosis of changes in the system of science or ultimately formulates a normative claim as to how science should function in the face of far-reaching social challenges. It is precisely this oscillation between descriptive diagnosis and normative claim that has often been criticised (Shinn 2002). Nevertheless, many transdisciplinary projects have taken up the considerations associated with the Mode 2 concept for their problem-oriented research without dwelling on this tension between normativity and descriptive diagnosis. We will go into this in more detail in the last two sections.

2.2. Post-normal science

While Mode 2 and transdisciplinarity are closely and explicitly linked, the connection between transdisciplinarity and the concept of "post-normal science" is more implicit. In the central essays on post-normal science (Funtowicz & Ravetz 1985, 1992, 1993), the term transdisciplinarity does not appear, although there are numerous similarities (Ravetz 2010, p. 244), as we explain below. Alongside Mode 2, reflections on a "science for a post-normal era" (Funtowicz & Ravetz 1993), which deals with questions where facts are uncertain, values are contested, stakes are high and decisions are urgent (Funtowicz & Ravetz 1993: 744), represent an important point of reference in the debate on transdisciplinary research.

The concept of post-normal science was developed in the mid-1980s by the two science theorists Jerome Ravetz and Silvio Funtowicz. According to the two authors, the increase in risks brought about by scientific and technological progress leads to a changed relationship between science and society, in which how we deal with uncertainty and implicit values becomes more important (Ravetz & Funtowicz 1999: 641). The first parallels to the Mode 2 concept can already be seen here. The term post-normal science is an allusion to the concept of normal science used by the philosopher of science and physicist Thomas S. Kuhn, who distinguishes phases of normal science from those of scientific revolutions in his major work "The Structure of Scientific Revolutions". By "normal science", Kuhn means a mode of science in which scientific knowledge is cumulatively attained through the formation of theory and empiricism within the framework of a dominant paradigm (Kuhn 1996 [1962]: 9). Research takes place on the basis of an established and widely recognised theoretical foundation, and scientific findings are made that build on each other, as they have the same theoretical starting points. Scientific revolutions, on the other hand, are moments when the dominant scientific paradigm within a (sub)discipline comes under pressure due to new approaches and is replaced by a different perspective. According to Ravetz and Funtowicz, since around the end of the Second World War, modern science has had to contend with the fact that its findings and successes are accompanied by growing uncertainties and normative ambiguities[28] – particularly with regard to the consequences of science and technology – which makes phases of normal science in Kuhn's sense increasingly rare (Funtowicz & Ravetz 1993: 740). Uncertainties find their way into science in particular where experiments are not possible and scientific knowledge is instead gained with the help of mathematical models and computer simulations based on partly implicit, normative or uncertain assumptions (Funtowicz & Ravetz 1993: 742). The idea of a value-free science that identifies unambiguous truths is thus increasingly regarded as an illusion.

A further starting point for Ravetz and Funtowicz's considerations is the observation that the negative consequences of science and technology (in particular environmental destruction), which are becoming more and more observable and discussed, cannot be dealt with using the same type of science that produced those side effects. The "old" science would attempt to overcome the negative consequences of science and technology with advances in knowledge within the existing paradigm and technological innovations developed using this knowledge, which would, however, lead to further side effects. Thus, from a societal point of view, the mode of normal science has a self-destructive tendency (Funtowicz & Ravetz 1993: 742).

According to Ravetz and Funtowicz, in order to counteract this tendency, a new, post-normal form of science is needed that addresses uncertainties, reflects on controversial values, is aware of its value-bound nature and takes non-scientific perspectives and bodies of knowledge seriously and integrates them into the research process (Funtowicz & Ravetz 1992: 273, 1993: 741). This leads to a democratisation of scientific practice, or in the words of the two authors: "The activity of science now encompasses the management of irreducible uncertainties in knowledge and in ethics, and the recognition of different legitimate perspectives

28 Normative ambiguity here refers to the value-related ambiguity of a situation or issue. For example, the use of nuclear energy can be assessed as positive and desirable, as it represents a relatively CO_2-neutral source of energy compared to coal, but at the same time the problem of storing nuclear waste and the risk of nuclear accidents also suggest the opposite assessment. How this technology is scientifically assessed therefore also depends on the point of view of the observer.

and ways of knowing. In this way, its practice is becoming more akin to the workings of a democratic society, characterised by extensive participation and toleration of diversity" (Funtowicz & Ravetz 1993: 754).

Compared to Mode 2, the emphasis here is more on the need to democratise science. However, as with Mode 2, it remains unclear whether post-normal science is a normative concept and describes what socially relevant science should look like in order to make a contribution to tackling major human challenges such as climate change, biodiversity loss, poverty, etc., or whether it should be understood as a sociological diagnosis that postulates that a new type of science has emerged or is emerging through its confrontation with scientifically produced uncertainties and risks.

Having initially approached the post-normal science concept in abstract terms, the question now arises as to exactly what type of science is meant by post-normal science. In order to clarify this more precisely, Funtowicz and Ravetz distinguish between three policy-relevant forms of knowledge production and the associated problem-solving techniques on the basis of the two dimensions of "systemic uncertainties" and "decision stakes" (Funtowicz & Ravetz 1993: 744ff.) (see Figure 13).

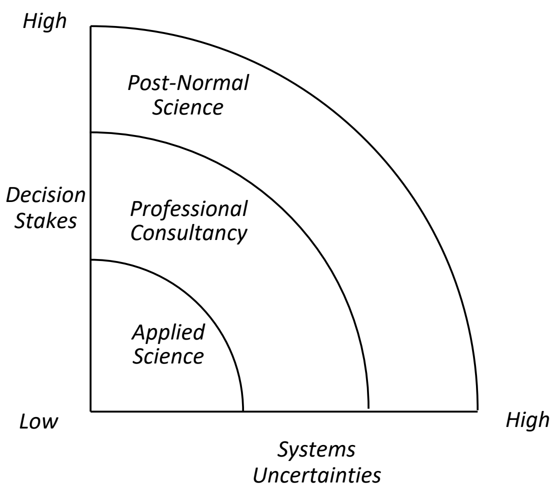

Figure 13: Forms of knowledge production and problem solving; source: Funtowicz & Ravetz (1993: 745)

The "decision stakes" axis describes the extent of the costs and benefits associated with solving a particular problem – i.e., the values that are "at stake" (both economic and social, such as justice or health) and the associated conflicts of interest. For example, the fight against the COVID-19 pandemic can be described as a problem that is a disaster if it fails, but delivers enormous benefits if it succeeds, and is accompanied by major conflicts of interest with regard to the different strategies proposed for solving the crisis. The "systems uncertainties" axis, in turn, represents the degree of complexity of the problem and the associated uncertainties with regard to its assessment. The COVID-19 pandemic, for example, was as an extremely complex systemic risk that encompassed multiple crises (education crisis, economic crisis, health crisis, etc.), for which there were no clear and unambiguous solutions (Funtowicz & Ravetz 1993: 744). The two axes are linked in that, if the level of scientific knowledge is uncertain (high systems uncertainties), the assessment of the level of knowledge depends on the values at stake – and this varies between different groups of actors (e.g., the affected population or political decision-makers) (Ravetz 1999: 650). Among other things, this reflects the aforementioned value-bound nature of science.

Based on these two axes, Funtowicz and Ravetz then distinguish between three policy-relevant forms of knowledge production, as forms of science that contribute findings and solutions for the real-world problems that political decision-makers (have to) deal with. In the field of applied science, the problems to be solved are of low uncertainty and there are relatively clearly defined, unambiguous problem-solving options available in the established body of scientific knowledge (low systems uncertainties), so that there is little room for decision-making conflicts (low decision stakes). Here, established theories and standardised scientific methods can be used to develop reproducible solutions to problems. The field of professional consultancy comprises applied science and also issues that are characterised by greater uncertainty and higher decision stakes. As these are context-related yet more complex problems that are sometimes dealt with on behalf of clients and sometimes on behalf of politics and society, it is not possible to apply standardised problem-solving procedures or recommendations that are beyond question or doubt, because of the many different objectives and assessment criteria. Instead, the solutions that are developed depend on the context, may be risky and cannot be easily reproduced or applied to other problems. Finally, the field of post-normal science is characterised as follows: "The problem situations that involve post-normal science are ones where, typically, facts are uncertain, values in dispute, stakes high, and decisions urgent" (Funtowicz & Ravetz 1992: 253). There are no undisputed theories or reliable methods of problem solving. Instead, possible solutions are highly controversial due to conflicts of interest. The expertise that each interest group puts forward to strengthen its position can be refuted by other groups using their own counter-expertise. Many environmental conflicts take this form (Ravetz 1999: 649). In relation to these three forms of knowledge production, basic research (referred to above as Mode 1) can be located at the intersection of the two axes, because it is determined purely by internal scientific interests: claims or decision-making spaces that are external to science play no role here (Funtowicz & Ravetz 1993: 745).

As scientific findings in the field of post-normal science are subject to great uncertainty with regard to their scope, validity and consequences, they are not perceived as truths by those affected. Instead, values and interests play a significant role in the evaluation and assessment of scientific findings and the problem-solving approaches derived from them. For example, nuclear power is perceived as a high-risk technology on the one hand and as an effective means of combating climate change on the other. Such problems lead Funtowicz and Ravetz to conclude that quality assurance in the field of post-normal science cannot be carried out solely by internal scientific actors and methods, in particular peer review procedures by other scientists, but that all actors affected by the scientific findings must be involved in an open dialogue to evaluate those findings. In this context, Funtowicz and Ravetz speak of an "extended peer community": "The contribution of all the stakeholders in cases of Post-Normal Science is not merely a matter of broader democratic participation. [...] For these new problems, quality depends on open dialogue between all those affected. This we call an 'extended peer community', consisting not merely of persons with some form or other of institutional accreditation ('stakeholders'), but rather of all those with a desire to participate in the resolution of the issue" (Ravetz 1999: 651). The idea of an extended peer community is also linked to the claim that not only the academic knowledge of scientists should be taken into account in the research process, but that practitioner and lay knowledge should also be included (Funtowicz & Ravetz 1993: 754f.). For example, when dealing with local ecological problems, the everyday knowledge and experience of the local population, who have observed or been directly involved in the development of the problem, is of great importance (Wynne 1996). However, this is not about turning lay people into scientists, but rather about integrating non-academic knowledge into the research process and opening up the discussion and evaluation of scientific findings and proposed solutions to all actors in society (Funtowicz & Ravetz 1992: 254). Funtowicz and Ravetz believe that this is always necessary when, as explained above, a lack of reliable facts means that a particular problem has no clear solutions and any possible solutions are associated with different advantages and disadvantages for different social actors.

2.3. Criticism of Mode 2 and post-normal science

The concepts of Mode 2 and post-normal science have been heavily criticised time and again since their emergence, particularly from the perspective of the sociology of science. Most of the criticism applies equally to both concepts (a brief summary of the main points of criticism can be found in Nowotny et al. 2003: 189f.). The criticism is primarily directed at three points: a) a lack of empirical evidence, b) an insufficiently complex understanding of the relationship between science and society, and c) the subjugation of science to political and economic imperatives.

Peter Weingart in particular argues that there is a lack of empirical evidence for the emergence of a new form of knowledge production and that Mode 2 and post-normal science should be seen as a normative programme for the transformation of science, but not as an evidence-based, descriptive diagnosis of an observable change (Weingart 1999: 48). This is exacerbated by the fact that the fundamental texts on Mode 2 and post-normal science make no clear distinction between normative claims and descriptive argumentation, and their empirical references are also of a more anecdotal, experience-based nature and not based on a systematic analysis.

Furthermore, critics argue that the strong emphasis on the de-differentiation or merging of science and society, which – as shown – can also be understood as a normative claim, has the consequence that existing differences between different bodies of knowledge (especially between lay knowledge and academic knowledge), forms of the division of labour and the different functional logics of different systems (such as science, economy, politics, civil society, etc.) are downplayed and sometimes deliberately ignored (Shinn 2002: 604). The lack of theoretical underpinning for the de-differentiation hypothesis also results in an insufficiently complex understanding of the relationship between science and society.

Critics also take issue with what they see as an implicit assumption in Mode 2 and post-normal science that science should submit to political and economic imperatives and ensure that its findings can be utilised as effectively as possible both politically and economically. Behind the claim of democratising science thus lurks the danger of a neoliberal restructuring of the relationship between science and society (Maasen & Lieven 2006).

While the criticism about the inadequate theoretical and empirical basis of the de-differentiation hypothesis is entirely understandable and justified, we would like to take a more nuanced look at the criticism about the normative orientation and "neoliberalisation" of science. Such criticism is certainly appropriate when researchers in transdisciplinary projects unquestioningly adopt political and/or social guiding principles, e.g., regarding sustainability, resilience or economic viability, or view these as externally given guidelines. It is also problematic if political and/or social guiding principles become established as a set research objective and evade scientific legitimisation and critical reflection. In this case, scientific objectives would actually be subject to non-scientific interests. However, this is not a general problem of transdisciplinary research, as outlined in the concepts of Mode 2 and post-normal science, but rather depends on the context of the specific research project, how the research is embedded within organisations, as well as the researchers' ability to reflect and their scientific diligence.

3. Transdisciplinarity as a research principle of social ecology

Intensifying socio-ecological crises and their public discussion has led to the establishment of a field of research over the last three decades in which environmental problems are not understood and analysed as mere natural phenomena, but as socio-ecological problems. There are various names for this field of research, such as human ecology, integrated environmental research, sustainability research, and social ecology (Becker 2016: 392). In our view, social ecology is the most succinct description.

Social ecology examines the interrelationship and interactions between society and the environment (Becker 2016: 395f.) – not from a purely sociological perspective, like environmental sociology, but in an integrative way. An analysis of social processes of perception and actions is combined with an analysis of the ecological effects and repercussions of those actions. It therefore takes an integrative view of social, technical and biophysical systems, their interactions and the resulting consequences. The contribution of environmental sociology is thereby primarily in the analysis of the relationship between the environment, technology, and society.

Socio-ecological problems (e.g., biodiversity loss or the ecological consequences of car use) are always real-world problems that transcend the boundaries of scientific disciplines and cannot be reduced to objects of investigation within individual disciplines (Becker 2016: 264). Furthermore, they are typically perceived, described and assessed very differently by various scientific and non-scientific actors. As described above, such problem configurations invite a transdisciplinary research approach, which is why socio-ecological research usually takes place in a transdisciplinary mode (Becker 2016: 393f.). In the following, we will provide a more detailed explanation of the transdisciplinary approach in social ecology as it has become established in German-speaking countries and beyond, particularly on the basis of work carried out by the Institute for Social-Ecological Research (ISOE) in Frankfurt and the Department of Environmental Systems Science at ETH Zurich. It is a concretisation of transdisciplinarity as a research principle for scientific practice, which borrows in various ways from Mode 2 and post-normal science.

The central element of transdisciplinary research in social ecology is the concept of knowledge integration. This refers to the need to relate different types of knowledge to each other and integrate them in order to be able to deal with socio-ecological problems. Knowledge integration is necessary due to the multi-layered nature of the research objects and the fact that different disciplines and non-academic actors must be involved in the research process, so that practical and socially relevant solutions can be developed for these complex problems and contributions to scientific knowledge can be made (Jahn et al. 2012). The various actors involved in the transdisciplinary research process possess different knowledge stocks and can therefore also contribute, in varying degrees, to the expansion of knowledge. In the field of transdisciplinary research, a distinction is generally made between the following three stocks of knowledge (Hirsch Hadorn et al. 2008; Becker 2016: 245):

a) System knowledge refers to the relationships and processes that have led to a particular problem. It is a deeper understanding of certain issues and conditions, and compiles factual knowledge about "the current state of play". The concept of system knowledge thus corresponds to the classical understanding of scientific knowledge.
b) Orientation knowledge refers to values and goals that guide action and represents knowledge about the desirability and acceptability of different target states. This is normative knowledge about the direction in which a certain problem state should be changed.
c) Transformation knowledge refers to the way in which a specific target state can be achieved. It describes knowledge about how a current state can be transformed into a target state through practical problem solving.

While researchers are primarily carriers and producers of system knowledge, non-academic actors in transdisciplinary research contexts are mainly responsible for providing orientation and transformation knowledge. The aim of knowledge integration is to bring the various actors together and to relate and link their individual knowledge stocks to one another. This linking is necessary because the solution to the problem at hand is based on the interaction between the various knowledge stocks: Knowledge about a practical solution to the problem (transformation knowledge) can be derived from analytical knowledge about the origins of the problem (system knowledge) and is also dependent on knowledge about the target state that the solution should be aiming towards (orientation knowledge).

The transdisciplinary research process for dealing with real-world problems can be roughly divided into three phases (for more on the transdisciplinary research process in general, see Jahn et al. 2012). In the first phase, the problem transformation phase, a real-world problem is translated into a scientific problem so that it can be addressed by science. A real-world problem is by definition a problem articulated by social actors, so the way in which the problem is perceived and described varies depending on the orientation knowledge of the relevant actors. This means that a precise definition of the problem can only take place with the involvement of the relevant social actors. The constantly high CO_2 emissions caused by motorized individual transport is an example of a socio-ecological, real-world problem, which we will use to illustrate the three phases. This problem must now be translated into individual scientific questions that can be addressed by the relevant disciplines. From a sociological perspective, for example, the social significance of mobility in general and automotive transport in particular could be examined; from an engineering perspective, researchers could focus on questions of (energy) efficiency and the design of passenger transport options with lower CO_2 emissions. In the second phase, the phase of knowledge generation and interdisciplinary integration, the researchers involved in the project work on their respective (disciplinary) questions. What is important here is that the individual questions must be coordinated with each other or already formulated in an interdisciplinary manner, so that they can be brought together to create an interdisciplinary perspective on the problem once the results are available. This creates system knowledge that combines the findings of different disciplines to create the most comprehensive understanding possible of the logic and dynamics of the problem. In the example introduced above, this means that the researchers would develop a comprehensive picture of the social, political, technical, etc. factors that lead to the constantly high CO_2 emissions caused by motorized individual transport. In the third phase, transdisciplinary integration, the researchers work cooperatively to derive and develop problem-solving approaches. These can range from recommendations for action to guidelines or specific products. In transdisciplinary integration, the involvement of non-academic actors takes centre stage because, as the primary carriers of transformation and orientation knowledge, they are best placed to assess the practical feasibility and acceptability of the various problem-solving approaches.

This type of practical transdisciplinary research outlined above has become firmly established over the last two decades. Unlike Mode 2 and post-normal science, it has rarely been the topic of major debates. However, the debate about problem-oriented research practices has been reignited by the emergence of so-called transformative science, some of whose pioneers draw on ideas about transdisciplinarity. In the following section, we will therefore conclude with a look at transformative science and the associated real-world laboratory research.

4. Transformative science and real-world laboratory research

The notions that scientific knowledge production should be democratised and research should be oriented towards real-world problems are inherent to different concepts of transdisciplinarity, and these ideas have gained greater momentum in recent years through calls for transformative science (Augenstein et al. 2024). At the heart of the idea of transformative science is the demand that science should become a catalyst for social transformation processes geared towards achieving sustainability. It aims to initiate, drive and, if possible, accelerate transformation processes by developing and testing technical and social innovations in the real world, with the extensive participation of non-academic actors (especially from civil society). Although it is related to transition research in terms of concept and content, transformative science is different in that it does not "only" want to observe, describe and analyse transformation processes in order to generate system knowledge, but rather wants to actively serve as a driver of transformation processes (Schneidewind et al. 2016; Augenstein et al. 2024).

Transformative science is not the same as transdisciplinarity. It operates in a transdisciplinary mode, but claims to go beyond the goals of transdisciplinary research. Accordingly, Uwe Schneidewind and Mandy Singer-Brodowski (2013) refer to transformative science as "Mode 3" of knowledge production, following Gibbons et al. (1994) (see also Table 3). While transdisciplinary research has no explicit normative commitment to *one* target dimension, transformative science is explicitly committed to the goal of sustainability. This means that the innovations developed through transformative research are always assessed according to their contribution to sustainable development, even if it remains unclear and controversial how this development can be put into action. Transdisciplinary research projects primarily incorporate non-academic actors as consultants, particularly to assist with the definition of the problems prior to the practical research process and with the subsequent development of problem-solving approaches. By contrast, transformative science gives non-academic actors the role of co-researchers in the implementation of the research agenda. Furthermore, while transdisciplinary research aims to contribute to solving real-world problems, transformative science aims to actively change society itself (Schneidewind et al. 2016). This demonstrates an intensification of the claim regarding the de-differentiation of science and society, whereby it must be stressed that transformative science does not demand that the entire science system should be transformative, but instead only parts of it.

The central research format in transformative science is the so-called real-world laboratory in which real-world experiments are carried out. The term "real-world experiment" is borrowed from the work of Matthias Groß et al. (2005) (see also Groß 2006). To analyse different (historical) case studies in which scientific knowledge was applied in real-world contexts, i.e., outside the laboratory (e.g., waste disposal, livestock farming, renaturation projects), Groß and his colleagues developed a typology of experimentation. This typology facilitates a more detailed definition of the characteristics of real-world experiments, in contrast to laboratory experiments (see Figure 14).

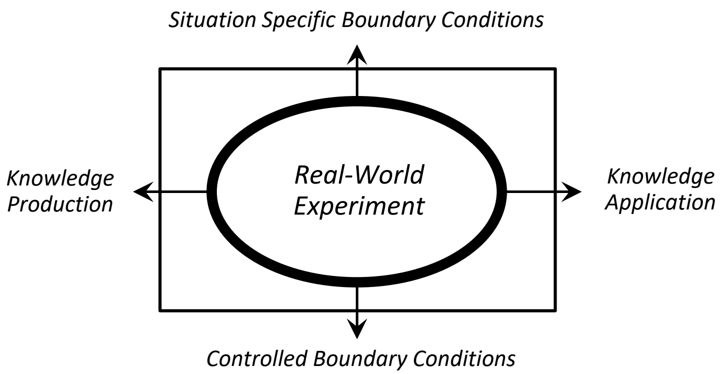

Figure 14: The typology of experimentation; source: own illustration based on Groß et al. (2005: 19)

This typology of experimentation spans two dimensions. The horizontal dimension indicates whether the respective experiment is aimed more at the generation or the application of knowledge; the vertical dimension indicates the degree to which any constraints can be controlled. In this respect, real-world experiments represent a hybrid form of experimentation in which the objectives of knowledge generation and knowledge application are linked and the constraints can only be partially controlled and cannot be systematically reconstructed (Groß et al. 2005: 16; Groß 2006: 47-48). Real-world experiments take place outside scientific laboratories in real-world settings (e.g., in urban spaces), which means that it is never possible to simultaneously control all the factors that could potentially influence the outcome of the experiment. They are also aimed at dealing with specific real-world problems.

The organisational framework for a real-world experiment is the real-world laboratory. Real-world laboratories are concrete locations or contexts such as a neighbourhood, an eco-village, a nature reserve, an energy cooperative or similar, within which transformation processes are initiated with the help of real-world experiments and the resulting interactions between technology, environment and society are made observable (and also influenceable) in situ (Bergmann et al. 2021). The aim is to learn about the transformation processes.

The principles of co-design and co-production are of particular importance in real-world laboratories (Mauser et al. 2013). Both principles represent and emphasise the participatory nature of real-world laboratories. Co-design refers to the involvement of all relevant non-academic actors in the development of the research agenda. Co-production refers to the participatory implementation of real-world experiments and the generation of knowledge, in which civil society actors are involved as co-researchers. How this can be organised and which forms of involvement are justified is highly situation- and context-specific, due to the experimental and performative nature of real-world laboratories. In any case, the classic questions regarding inclusivity and the fairness of the participation processes inevitably arise (Rowe & Frewer 2000). The very specific type of participation that is possible within the framework of narrowly defined real-world laboratory research can also be viewed as problematic, because this runs the risk of losing touch with public controversies and the participation aspirations of certain population groups. The solutions generated in real-world laboratories would then be regarded as sham solutions and not "socially robust". In addition, there is also a risk that real-world laboratory research will take on a strongly instrumental character due to its focus on utility and achieving sustainability, and that critical reflection about the meaning and objectives of experimental activities will be pushed to the background. This also touches on the question of what a critical transformative science could look like (Wittmayer & Hölscher 2017: 93).

Finally, the question arises as to the relationship between transformative science or real-world laboratory research and transdisciplinary research. As already mentioned, it is usually emphasised that real-world laboratory research takes place in a transdisciplinary mode (Schäpke et al. 2018), however, transdisciplinary research and real-world laboratory research have different focuses in terms of knowledge production. Real-world laboratory research focuses on the generation of orientation knowledge and transformation knowledge, while transdisciplinary research focuses on the generation of system knowledge (even though it also takes orientation knowledge and transformation knowledge into account). Accordingly, Thomas Jahn and Florian Keil point out that real-world laboratory research begins where transdisciplinary research ends (Jahn & Keil 2016). Real-world laboratory research can thus be understood as the implementation phase of transdisciplinary research processes, during which it is possible to experimentally evaluate the resulting transdisciplinary knowledge in a real-world setting and find out the extent to which and under what circumstances it is "socially robust".

5. Outlook

Both transdisciplinary research and (transformative) real-world laboratory research on socio-ecological problems fall short without social science expertise, as without it such research fails to take into account the mutual influence society and the environment have on each other. This raises the question of what specific contributions (environmental) sociology can make to transdisciplinary research projects or real-world laboratory projects. Six points can be highlighted in this regard. Firstly, environmental sociology provides theories and concepts about the interplay between technology, science, society, and the environment, which provide information about underlying interpretations and patterns of action (e.g., lifestyle approaches or practice theories), social structures (e.g., the theory of society-nature relations or systems theory) and their historical development (e.g., theories of social change). These approaches serve firstly to empirically analyse socio-ecological problems and secondly to provide a framework for integrating the findings of different scientific disciplines. Secondly, environmental sociology not only provides specific knowledge about (institutional) procedures and processes for shaping society-nature relations, but also about social forces of inertia (e.g., insights into the role of power in political decision-making processes, about the conditions for action at different levels of society or on the effect of civic participation processes), which are of particular relevance for the development of solutions to socio-ecological problems. Thirdly, insights into the mechanisms involved in the social construction of the environment and environmental risks, as well as the role of value judgements in this construction process, are of particular importance for dealing with socio-ecological problems. In this respect, environmental sociology can draw attention to the variable social character of environmental perceptions and knowledge and thus enable critical reflection on different perspectives during the problem-solving process. Fourthly, in transdisciplinary or real-world laboratory research practices, sociologists can act as process designers who facilitate processes of knowledge integration and, in particular, the involvement of non-academic actors on the basis of their knowledge about patterns of action and interpretation. The discipline of sociology with its understanding of social processes and social interaction is particularly suitable for this. Fifthly, methods of qualitative and quantitative social research are relevant for evaluating the impact of real-world experiments and behaviour-related interventions. That is why this kind of methodological expertise from the field of social research is also required. Sixthly, as a "science of reflection", sociology has the potential to scrutinise and make visible the inevitable but often unconscious selectivity of transdisciplinary processes. The specific design of recommendations for action or socio-technical innovations that result from transdisciplinary and real-world laboratory research always depends on the situational possibilities and circumstances, as well as on the conscious and unconscious decisions made about which non-academic actors are involved in the research process and how. This results in exclusions and blind spots that prevent certain types of recommendations for action and socio-technical innovations etc. from the outset.

(Environmental) sociology can therefore make important contributions towards transdisciplinary research and real-world laboratory research. But what does it mean for environmental sociologists to be involved in such research? Transdisciplinarity and real-world laboratory research go hand in hand with cooperation and exchange with other scientific disciplines and non-academic actors. This makes it necessary to present one's own concepts, terms, theories and methods in a way that is understandable to others and to actively search for theoretical and empirical interfaces with other disciplines. Without the ability to communicate across different interfaces, transformative or transdisciplinary cooperation cannot succeed. In addition, there must be a willingness to actively engage in dealing with social problems. This cannot be done from the heights of the academic ivory tower. Nevertheless, for the sake of scientific rigour, it remains necessary to maintain a critical distance from the object of investigation.

What students can take away from this chapter:

- Knowledge about what is meant by transdisciplinary research, Mode 2, post-normal science, and real-world laboratory research
- An understanding of problem-oriented research on socio-ecological problems
- An understanding of the difficulties of knowledge integration in transdisciplinary research
- An understanding of the relationship between science and society

Recommended reading

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Nowotny, H., P. Scott & M. Gibbons, 2003: Introduction: "Mode 2" revisited: The new production of knowledge. *Compact presentation of the Mode 2 concept, which also includes a response to the criticisms of the original text by Gibbons et al. (1994).*

Schneidewind, U., M. Singer-Brodowski, & K. Augenstein, 2016: Transformative science for sustainability transitions. *Programmatic presentation of the concept and goals of transformative science.*

Weingart, P., 1997: From "Finalisation" to "Mode 2": old wine in new bottles? *Comprehensive critique of the Mode 2 and post-normal science concepts.*

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