PART III:
A TRANSDISCIPLINARY MIX: CLIMATE CHANGE, POLITICS AND FINANCE

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Transdisciplinarity: Theory and Visions on Global Transdisciplinary Processes for Adapting to Climate Change*

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Abstract

Transdisciplinarity, which has become a third mode of using science, supplements disciplinarity and interdisciplinarity. This contribution discusses different notions of transdisciplinarity and introduces into theory, methodology and practice of transdisciplinarity. The core of transdisciplinarity is the integration of different types of epistemics (i.e. ways of knowing) from science and societal actors and systems. Ideally, transdisciplinarity relates abstract, analytic academic rigor with contextualised, experiential intuitive knowledge/wisdom of different key actors from practice. Transdisciplinary is a key methodology of sustainable transitioning and the coping with ill-defined problems such as coping with climate change. The article elaborates how transdisciplinary processes differ from other forms of applied research and participatory research such as action research, public participation, participatory research, or consultation. It is shown how different methods of case/system representation, case/system evaluation and case/system transformation may serve for different types of knowledge integration in transdisciplinary processes The functions of transdisciplinarity, i.e. capacity building, consensus building, mediation and legitimisation are identified and discussed.

A. Goals and Variants of Transdisciplinarity

This paper reviews how *transdisciplinarity* is distinguished from both *interdisciplinarity* and *disciplinarity*. The distinction between *transdisci-*

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* This paper is based on Scholz (2011:Chapter 15), used with permission, and has been partly reworked.

plinarity research and *transdisciplinary processes* is introduced. While there have been different interpretations of transdisciplinarity, this article advocates transdisciplinary processes that involve authentic collaboration between science and society, including representatives from industry, government, administration, different stakeholder groups, and the public at large. Such collaborations, as described here, emphasise mutual learning, joint problem definition and knowledge integration. Transdisciplinary processes should produce relevant, socially robust knowledge, i.e. knowledge that empowers society to cope with societal relevant problems, and which feeds back to scientific knowledge-generation and theory-building.

To initiate a transdisciplinary process, facilitators can employ techniques such as embedded case study methods to structure and organise work. These methods support problem representation and modelling, problem evaluation, development, and transition of the real-world problem. After a brief introduction of these methods, a step-by-step example is presented of a transdisciplinary process in Switzerland – one which has used these methods to develop a sustainable business future in harmony with the environment. Finally, the functions of transdisciplinary processes are described, such as capacity-/competence-building, consensus-building, analytic mediation, and legitimisation of public policy.

There is a practice of more than 20 years of transdisciplinary processes on sustainable transitions of regional, urban and organisational processes.[1] In the case of nuclear waste disposal, transdisciplinary processes have been applied to sustainable policy transformations.[2] The *why* and *how* of global transdisciplinary processes are presented, in which people involved in transdisciplinary case studies in different parts of the world may learn about how to adapt to climate change, and in what way social adaptation processes can inform each other.

I. Why Transdisciplinarity?

Collaboration between science and society is often requested if uncertainty arises about substantial changes in human-environment systems, such as the introduction of a new technology or new medical pharmaceuticals, diag-

1 Scholz (2011); Scholz et al. (2006).
2 Krütli et al. (2010); Scholz et al. (2007).

noses or therapies. Other problems that could benefit from collaborative processes between science and society are the finding of mitigation, adaptation, policy or decision strategies when facing fundamental changes to the natural or social environment, for instance, such as those due to natural hazards, climate change, resource scarcity or changing cultural settings.

It is argued here that, from the perspective of society, transdisciplinarity provides an efficient use of knowledge for coping with complex, socially relevant problems; it provides societal capacity-building and bridges the growing gulf between many areas of research and the public. This equips society with a better understanding of how technologies or the natural environment work, and how the natural environment interacts with man-made systems. Consequently, transdisciplinarity can permit us to master the new and cope more adequately with the unknown both from a scientific and a societal perspective, e.g. with regard to inventions such as nanotech articles. At the same time, transdisciplinarity stimulates academic research by highlighting phenomena, issues and emerging questions that require scientific reflection, and by feeding experiential knowledge into the research process. Furthermore, it frees science from the cumbersome implementation problem. In other words, instead of science having to face the challenge of gaining public understanding, acceptance or appraisal of something ingenious, but which is then rejected for 'non-academic' reasons, transdisciplinary processes put science into practice from the very beginning. Transdisciplinarity is, as will be elaborated, an efficient means of using knowledge in decision-making – at least in certain types of pro-democratic, civic societies.[3]

II. Definition and Notions of Transdisciplinarity

The term transdisciplinarity is occasionally referred to as *perfected interdisciplinarity*, or as the transfer of concepts or methods from one discipline to another. In the first definition of transdisciplinarity by Jantsch, as the "multi-level coordination of [an] entire education/innovation system",[4] the 'beyond science' notion of 'trans'-disciplinarity is highlighted. Since there is some confusion about the distinction between interdisciplinarity and transdisciplinarity, these concepts are briefly defined below.

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3 Almond (2000).
4 Jantsch (1972:221).

Disciplines are characterised by objects and (core) methods by which certain problems are approached. For example, the discipline of mathematics deals with relationships between symbols and numbers by the method of proof. Similarly, the purview of the discipline of pharmacy is to investigate the impact of certain chemicals (called *pharmaceutical drugs*) on diseases by the use of laboratory experiments and clinical trials.

Interdisciplinarity is established by the fusion of concepts and methods from different disciplines. A metaphorical example of fusion is the saxophone, which emerged from the clarinet and the trumpet. Biochemistry, the study of chemical processes in living organisms, e.g. investigating reactions between proteins and other molecules, can serve as an example of an interdisciplinary field – at least, that is, before it became established as a discipline. The experimental method is a pillar of this field. The term *industrial food web*, used in the emerging domain of industrial ecology, can also be taken as an integrated concept.

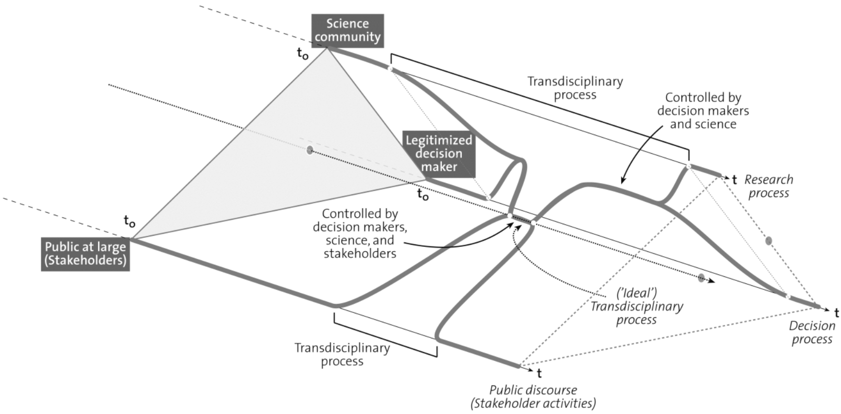
Transdisciplinarity is fundamentally different from interdisciplinarity. Most of today's definitions of *transdisciplinarity* include the fact that it goes beyond science, in the sense that it "… deals with relevant, complex societal problems and organizes processes [that relate knowledge and values of] agents from the scientific and the non-scientific world."[5]

There are different notions of transdisciplinarity. This contribution refers to the Zurich 200 definition.[6]

Disciplines efficiently organise the methods and systematised knowledge about the material-biophysical-technological world, as well as the social-cultural-epistemic world. Interdisciplinarity merges concepts and methods from different disciplines for a better understanding and to better explain certain issues, phenomena and processes that cannot be sufficiently explained from a single disciplinary perspective. Transdisciplinarity organises processes that link scientific, theoretical and abstract epistemics with real-world-based experiential knowledge, outside academia; and it relates human wisdom to the analytical rigour of science and academic methodology.

5 Scholz et al. (2000:447).
6 See Scholz (2011:377).

Figure 1: Transdisciplinary Processes as Interface and Mutual Learning among Three Types of Actors



In Figure 1, actors from the science community, the public at large, and legitimised decision-makers are involved in research processes, public discourses or stakeholder activities, and decision processes, respectively. When the actors leave their primary processes (indicated by bold grey action lines in Figure 1) and join in on a collaborative, power-balanced effort, we can call this a *transdisciplinary process*.

Distinguishing transdisciplinary *research* from transdisciplinary *processes* is important. Transdisciplinarity, according to the Zurich 2000 definition described in the next section, organises mutual learning among science and society that can generate socially robust knowledge. For the most part, this mutual learning takes place in transdisciplinary processes in which members from the science community interact with decision-makers, stakeholders or the public at large. Transdisciplinary processes differ from consultancy and contracted research with respect to power-sharing and direction of involvement, i.e. in terms of who participates in whose process. In consultancy and contracted research, scientists operate in the action space of the legitimised decision-maker, who allows science to participate. Members, knowledge and results from the science community become part of the decision process. Here, the legitimised decision-maker ultimately decides how the skills and knowledge of scientists are used during the process, and how outcomes and results are communicated and utilised.

Usually, a transdisciplinary process emerges if a legitimised decision-maker and members from the science community notice that they have a joint interest in a complex, relevant phenomenon that can be better understood and dealt with if knowledge from practice and from science is integrated. Typical examples are sustainable transitions of regional systems caused by, for example, the overexploitation of natural resources (including pollution), or by adapting to changing environmental conditions.

The ways in which scientists, legitimised decision-makers and the public at large can collaborate are illustrated in Figure 1, which shows four horizontal time axes. At the bottom front, we find the public at large, whose priority is to sustain and organise life. This public opinion-building activity, shown as public discourse (in the foreground), represents the cultural-social side of human systems. The top arrow represents the activities of the scientific community, i.e. teaching, in-service training, investigating, etc. Together these make up the research process. At the bottom rear, we find the legitimised decision-maker, whose activities make up decision processes. A legitimised decision-maker can be a national or local government, a local environmental agency that has certain responsibilities, or a property owner such as a landowner or a company director who makes or plans decisions. If a legitimised decision-maker and scientists participate in a transdisciplinary process, they leave their action spaces for a certain period and collaborate. A situation of equal control between decision-makers and scientists – i.e. the transdisciplinary process – is represented by the plane bordered by the research process and the decision process lines in Figure 1.

Here, scientists and decision-makers leave their primary domain (research and decision processes, respectively) and establish a joint transdisciplinary process. In this process, they jointly agree on the topic or specific system to be investigated, e.g. defining the spatial and temporal system boundaries, leading to a joint problem definition.

Members of the public at large can be affected or feel concerned by the decision process and may organise themselves into interest or stakeholder groups. Often, these stakeholders or members of the public at large then participate in the transdisciplinary process (in a limited time period: see middle bold line of Figure 1). However, sometimes these groups can formally – or even informally – control the process. An ideal transdisciplinary process involves all three groups – researchers, decision-makers and stakeholders – in a collaborative, power-balanced relationship. In Figure 1, this ideal transdisciplinary process takes place at the transdisciplinary process line that runs through the centre of the triangle. It should also be noted that industry, as a specific stakeholder in society, may become a key player in a transdisciplinary process.

Transdisciplinary research takes place before, during or after a collaborative process, to provide preparatory research, support information, or follow-up research, respectively. The transdisciplinary *process* provides important input for transdisciplinary *research*, which is controlled by scientists, who can in turn ensure that results are produced through rigorous research methods.

III. Different Interpretations of Transdisciplinarity

Transdisciplinarity and interdisciplinarity have been defined differently at different times and by different scientific domains and disciplines. Table 1 refers to the relevant discussion in the environmental and sustainability sciences. The first, moderate interpretation of 'going beyond science' was suggested by Mittelstrass (1996), who argues that "… transdisciplinarity is primarily a form of research addressing and reflecting on issues in the life-world."[7]

Referring to a distinction of scientific activities suggested by Gibbons et al. (1994), we call this *Mode 1* transdisciplinarity, as such scientific work can be found in traditional disciplines.

As an example of Mode 1 transdisciplinarity, we can take Nobel Laureate Amartya Sen's work on famine and poverty. Sen's work is characterised by classical disciplinary economics; however, many of his papers include ethical ideas – and, thus, are rather of an interdisciplinary nature – and deal, for instance, with inequality and child survival in Bangladesh, India, Pakistan, and North Africa, among other countries.[8] Though he is as a classical economist, Sen's work is interdisciplinary and is, according to Swedberg, "… ultimate[ly] concern[ed] … about the lives we can or cannot lead; about issues of the real world."[9]

Mode 1 transdisciplinarity differs from isolated thinking about the environment (and applied sciences), as it includes interperspectivity[10] and empathy, but not necessarily collaboration with others. Sometimes, pure problem-oriented research is denoted as being transdisciplinary.[11] Factually then,

7 Cited in Hirsch-Hadorn et al. (2008:28).
8 Sen (1999).
9 Swedberg (1990:339).
10 Giri (2002).
11 Jaeger & Scheringer (1998).

Mode 1 transdisciplinarity does not significantly differ from applied research, and is often linked to a 'truth to power' theory–practice relationship.[12]

The second definition of transdisciplinarity (Mode 2), which is here referred to as the *Zurich 2000* definition, resulted from the participation of 500 researchers and 300 practitioners at a conference in Zurich in 2000. This definition reads as follows: "Transdisciplinary research takes up concrete problems of society and works out solutions through cooperation between actors and scientists."[13]

From the perspective of scientific research, this conception of transdisciplinarity –

- organises processes of mutual learning among science and society
- integrates knowledge and values from society into research,[14]
- provides an appropriate research paradigm that better reflects the complexity and multidimensionality of sustainable development.

Following the Zurich 2000 definition, transdisciplinarity has been declared as the appropriate methodology by which sustainable development should be investigated and promoted.[15]

Transdisciplinary processes are periods of cooperation between scientists and practitioners to develop socially robust knowledge for coping with ill-defined, socially relevant problems, as described above. Transdisciplinary research deals with questions emerging from these processes. For the most part, this research is conducted without the participation of actors from the non-academic world who would normally be participating in the transdisciplinary process. However, we speak about transdisciplinary research only if it results from joint problem definition and a transdisciplinary process. Transdisciplinary research provides results that can be fed back to the body of science. Furthermore, transdisciplinary research is an element of the mutual learning process that takes place to develop robust orientations. This is the foundation for solving socially relevant problems, such as groundwater management, soil protection, or sea level rise. Thus, according to the Zurich 2000 definition, transdisciplinary research is simply research that is directed to, and conducted in the context of, transdisciplinary processes.

12 Pohl (2008).
13 Häberli et al. (2001:6).
14 Scholz et al. (2000).
15 Scholz & Marks (2001).

A third conception of transdisciplinarity can be called the *post-normal science approach*, as exemplified by Funtowicz and Ravetz.[16] A key to this approach is the assumption that real-world issues are so complex that the scientific results become just another voice or one vote within the agora of arguments in the real-world discourse. This is reflected in statements such as the following: “The faith in the truth and objectivity of science, established by Descartes and Galileo, is overthrown.”[17]

The post-normal view stresses that science has lost credibility, and that “… any genuine understanding of a technology must now take into account malevolence, … also of those applying it to anti-human ends.”[18]

It should be noted that the Zurich 2000 definition and the post-normal science understanding show many commonalities. Both approaches assume, for instance, that science incorporates values and world views in its investigations. However, it is important to distinguish between the different types of knowledge (*epistemics*) and constraints of producing knowledge in practice and in science. In the view presented here, experiential knowledge and scientific knowledge differ in their foundations, epistemological status, and the roles they play in different types of real-world problems. Taking the climate change example, we see that models of sea level rise are highly uncertain. Furthermore, they include unknown and unknowable assumptions about the development of the human population, prospective greenhouse gas emissions, technological development, or unknown future natural systems dynamics such as volcanic activities, El Niño-like cycles, or interactions with the biosphere, and there are huge uncertainties in many contextualised environmental research questions.[19] Nevertheless, there is a community of natural scientists[20] developing models, theories and predictions about climate change that, in their genesis, status, precision, and validation strategies, differ from statements uttered by politicians, members of construction companies, etc. In addition, social scientists provide knowledge about drivers of and obstacles to human behaviour that are relevant to understanding adaptation processes. Thus, one should also be careful when stating that “science takes place in the agora”[21] of ideas, though it is acknowledged that scientific

16 Funtowicz & Ravetz (1993, 2008).
17 Funtowicz & Ravetz (2008:364).
18 (ibid.).
19 Van de Kerkhof & Leroy (2000).
20 Waert (2003).
21 Gibbons & Nowotny (2001:79).

statements become relative in complex contextualisation. Thus, both the Zurich 2000 definition and the post-normal science approach assume that science only provides one type of epistemic, and it is vital to be aware that science can err.

One should also note that the Zurich 2000 definition is compatible with a constructivist perspective: it not only acknowledges that truth has a 'social nature', but it is also understood that the science community decides what is considered true or valid. As stated earlier herein,[22] this even holds true for mathematics, for example, as there are many cases where no single scientist is able to verify all prerequisites included in a complex proof of a theorem.[23] However, in the Zurich 2000 definition, *science* refers to a normal science view – i.e. approaching a valid or 'true' description of reality as a reference system – that is lost in its post-normal variant.

In both the Zurich 2000 and the post-normal science definitions, scientists can play a double role: they can contribute as facilitators or moderators to establish an appropriate process, and they can contribute as scientific experts.

A fourth definition of transdisciplinarity has been shaped by Nicolescu[24] and the Charter of Transdisciplinarity.[25] This approach to transdisciplinarity shares many aspects of the Zurich 2000 and the post-normal science approaches. One such aspect is "acknowledging different types of logic".[26] What makes this approach unique is that it "constitutes a personal moral commitment" against the "spiritual and material self-destruction of human species",[27] challenging that the "dignity of the human being is of both planetary and cosmic dimensions".[28] Furthermore, the approach addresses the unity of knowledge that targets the integration of scientific, religious, transcendent, and other forms of knowledge. In the following sections, we refer to the Zurich 2000 definition of transdisciplinarity.

Table 1 offers a schematic representation of the four variants of transdisciplinarity discussed above.

22 See section A.II above.
23 Scholz (1998).
24 Nicolescu (2002).
25 (ibid.); De Freitas et al. (1994).
26 De Freitas et al. (1994:Article 2).
27 (ibid.:Preamble).
28 (ibid.:Article 8).

Table 1: Variants of Transdisciplinarity

Variant	**Essentials**
Mode 1 transdisciplinarity	Science becomes transdisciplinary if it reflects on real-life problems.
Zurich 2000 definition	There are transdisciplinary processes organising mutual learning between the science and the non-science communities, and transdisciplinary research which integrates knowledge and values from practice and science. Both processes deal with tangible, socially relevant, real-world problems. Practice and theory (science) have different reference systems. The transdisciplinary process features joint problem definition, representation and transformation ('problem-solving').
The post-normal science approach	Science becomes just one vote in an agora (*forum*, *marketplace*) of arguments solving real-world problems because of the uncertainties and incompleteness of knowledge, multitude of logics, etc.
The 'Charter of Transdisciplinary' approach	In addition to many aspects of Modes 2 and 3, a personal moral commitment and 'unity of knowledge' is needed.

IV. Sustainability Learning for Generating Socially Robust Knowledge

Facilitating transdisciplinary processes presents an opportunity for scientists to promote sustainability learning as a process outcome and, in turn, to use process outcomes to generate socially relevant, robust knowledge. In this section, we discuss the scientist's dual epistemic role in transdisciplinary processes. Transdisciplinarity endeavours to use scientific knowledge efficiently to cope with socially relevant problems. Whether and, if so, how this can be done depends on various constraints, in particular on the specific problem at hand and the given sociopolitical context. Here, sustainability, as a widely shared way of regulating ideas from many contemporary societies, is essential. Transdisciplinarity can be linked to processes where society can learn about sustainability. This is known as *sustainability learn-*

ing. How sustainability learning is related to transdisciplinarity is explained in the following way:[29]

> Transdisciplinarity can be said to evolve from special types of problems, i.e. real, complex, socially relevant problems, which ask for the integration of the knowledge of science and society (Burger & Kamber, 2003; Scholz et al., 2000; Thompson Klein et al., 2001). Most of these problems are strongly related to sustainable development (Blättel-Mink & Kastenholz, 2005). It can be said that planning and learning processes for sustainable development require transdisciplinarity as an approach (Meppem & Gill, 1998). This holds particularly true if the development and implementation of policies and mutual learning processes are targeted by the behavior of individuals, industries, organizations, and governments. We refer to the corresponding process as "sustainability learning".

With respect to 'ill-defined problems', sustainability learning requires processes that go beyond traditional consultation (i.e. transfer of information from society to science) and knowledge transfer (from science to society), which are common ways of using scientific knowledge. Here it is suggested that developing socially robust knowledge in transdisciplinary processes is a key element of societal capacity-building.

Generating socially robust knowledge involves a form of epistemics, which –[30]

- meets state-of-the-art scientific knowledge
- has the potential to attract consensus, and thus must be understandable by all stakeholder groups
- acknowledges the uncertainties and incompleteness inherent in any type of knowledge about processes of the universe
- generates processes of knowledge integration of different types of epistemics, e.g. scientific and experiential knowledge, utilising and relating disciplinary knowledge from the social, natural, and engineering sciences, and
- considers the constraints imposed by the context both of generating and utilising knowledge.

Here, "mutual learning between science and society"[31] is considered a key characteristic of transdisciplinary processes and sustainability learning. These processes should be characterised by –

29 Scholz et al. (2006:231).
30 Gibbons & Nowotny (2001); Nowotny et al. (2001).
31 Scholz (2000).

- joint problem definition, i.e. determining the actual problem that is being targeted by various stakeholders, and how the sometimes diverging views of these stakeholders can be integrated and agreed on
- joint problem representation, i.e. developing a language that provides a medium of representation for describing the object, content and changes (dynamics) of the object (this step includes problem structuring),[32] and
- jointly initiating a process of problem-solving (perhaps more properly expressed as *problem transition*), which is cost-effective, socially acceptable, scientifically sound, and competitive in the marketplace.[33]

Thus, mutual learning can be viewed as a process that can generate socially robust knowledge that can contribute to coping with challenging societal transitions.

Through the example of global warming, the nature of the problems involved in these transitions and the generation of socially robust knowledge can briefly be looked at. Global warming and its environmental impacts require significant adaptations. Today, it is unclear how these adaptation processes should proceed, or what they should look like. It is unclear which measures are technically feasible and socially acceptable, and how reasonable goals can be presented. Making a country more resilient and less vulnerable to climate change, for example, and making preparations that will help a country to avoid uncontrollable damage[34] are typically ill-defined problems. This holds true for lowland countries and islands such as Bangladesh, the Maldives or the Netherlands having to cope with rising sea levels, or in the case of adapting agriculture in semi-arid regions. Nobody knows exactly what target state can or should be attained, or what barriers need to be overcome to reach this state. Neither is it known which barriers – economic, environmental or social – are the most severe. Problem definition is, therefore, a particularly difficult task, especially with respect to financial payouts that correlate with who is affected (positively or negatively) by environmental impacts. Clearly, all this is linked to the ontology of ill-defined problems.

32 Checkland (2000).
33 Gibbons et al. (1994).
34 KfC (2008).

V. Key Messages

- Transdisciplinarity is essentially different from interdisciplinarity.
- There are different definitions of transdisciplinarity, ranging from reflecting on society (Mode 1 transdisciplinarity – see Table 1) via theory–practice collaboration- based definitions referring to capacity-building and knowledge integration in transdisciplinarity processes (which underlie this book), to definitions requiring a personal moral commitment.
- Transdisciplinarity is considered a powerful and efficient means of using knowledge from science and society with different epistemics serving societal capacity-building under certain political cultures.
- Transdisciplinarity can stimulate science to identify challenging research questions, and feed experiential knowledge into the research process.
- Transdisciplinarity organises and effects collaboration and mutual learning between theory and practice.
- Transdisciplinary processes, which are jointly controlled processes that involve scientists, decision-makers and stakeholders, should be distinguished from transdisciplinary research, which is controlled by researchers.
- Transdisciplinarity is a means of coping with complex, ill-defined (wicked), contextualised and socially relevant problems that today often suffer from a framework of uncertainty and ambiguity. Transdisciplinary processes can organise sustainability learning and capacity-building in society, and are essential for environmental literacy.
- Generating socially robust knowledge in transdisciplinary processes can be seen as a major goal of transdisciplinarity.

B. Implementing Transdisciplinary Processes

I. Sustainability Learning

If one considers transdisciplinarity as a procedure for sustainability learning or establishing socially robust knowledge, a critical question is what specific methods can be used to implement transdisciplinary processes.[35] This section describes a suite of embedded case study methods for supporting and

35 Reeger & Bunders (2009); Scholz et al. (2006); Scholz & Tietje (2002).

organising transdisciplinary processes. Sometimes acting as key facilitators during these processes, scientists draw on facilitation methods such as capacity-building, consensus-building and analytical mediation.

II. Methods for problem representation

Common issues that community members, practitioners and scientists jointly assess include the following examples:

- Representing how an infectious disease spreads[36]
- Identifying the causes of malnutrition, and
- Understanding the changes that have occurred in a certain system.[37]

A representation of a system or problem structure is often conceptualised by way of iconic mapping. Flow diagrams between concepts or pictures can represent cause–impact or means–end relationships. In principle, these types of representations are mental models. They are simple tools, well known from planning studies[38] or soft systems methodology.[39] Visualisations reveal much that is masked by verbal communication alone.[40] Visual literacy is ubiquitous and universal and, in some cases, a visualisation offers the only way of building a shared external representation of an issue as seen by both researchers and practitioners. The concept of "rich pictures" has been used to explore conscious and unconscious perception of problems and cases.[41]

Constructing a representation of a mental model includes many elements of an analytic process, as both the conceptual representation and the 'arrows' connecting these concepts ask for abstraction. The concept of "future workshops"[42] is a well-known approach that typically involves a two-day meeting that includes community members, researchers and administrators. These workshops result in consensus-building in respect of the current and future state of an urban setting, an institution, etc.[43] Under certain conditions, participants can become part of a transdisciplinary process. One goal of the

36 Kruse et al. (2003).
37 Hellier et al. (1999).
38 Schnelle (1979).
39 Checkland (1981); Checkland & Scholes (1990).
40 Cornwall & Jewkes (1995:1671).
41 Bell & Morse (2010a; 2010b).
42 Jungk & Müllert (1994).
43 Scholz & Tietje (2002).

process is to develop a joint problem representation of complex human–environment relations that are both understandable and acknowledged by the participants, and also compatible with system-theoretic scientific approaches. Facilitating the identification of a joint problem representation is an art that draws on methods which include verbal and system graphs from scenario analysis, system dynamics, material-flow analysis, supply chain analysis, etc. Creating a joint system representation that meets the problem at hand and that adequately deals with the different types of human-environment system complexities is an important part of the transdisciplinary process.

III. Methods of Process Management

Transdisciplinary processes require facilitation of the process of knowledge integration. What are needed here are aspects of moderation, balancing the power between different participants, and methods of integrating knowledge.[44] Process management includes the social processes of interaction between the participants and the content level. For the latter, certain types of integrated modelling such as the joint construction of scenarios can also play a role in a transdisciplinary process.

IV. Embedded Case Study Methods

Embedded case study methods are a specific set of methods that have been modified, advanced or newly developed in transdisciplinary case studies of sustainable urban development,[45] as well as regional[46] and organisational transitions.[47] Embedded case study methods were also applied to sustainable transitions of policy processes. In principle, these methods fall into four classes, namely A–D, as shown in Table 2. Transdisciplinary processes often start with case study team methods, which equip the group with strategies that allow them to work together effectively using approaches such as the experiential case encounter. We consider empathy and side change – i.e.

44 Hoffmann et al. (2009); Reeger & Bunders (2009); Scholz & Tietje (2002).
45 Scholz et al. (1996, 1997, 2004, 2005).
46 Scholz et al. (1995, 2002).
47 Mieg et al. (2001); Scholz et al. (2001); Scholz & Stauffacher (2007).

living or working in a real-world setting – a valuable way for researchers to gain a better understanding of what case agents know and understand. Empathy and side change also enhance the development of mutual trust, as the practitioner notices that the researcher is willing to leave the 'ivory tower'.

Table 2: Embedded Case Study Methods for Transdisciplinary Processes[48]

		The four types of knowledge integration			
					
Case study methods	**Key questions**	**Disciplines**	**Systems**	**Modes of thought**	**Interests**
(A) Case representation and modeling methods					
Formative scenario analysis (FSA)	What variables are crucial to the state of a system and to its change? What can be? What ought to be? What can happen?	XX	X	X	
System dynamics (SD)	Which variables are the most decisive in temporal dynamics? Which (counterintuitive) system change, outcomes, and feedback loops result from the dynamic interactions of the variables?	XX	X		
Material flux analysis (MFA)	What are critical fluxes in materials for the case? What are the sources and sinks of the system/case?	X	XX		
(B) Case evaluation methods					
Multi-attribute utility theory (MAUT)	How can different evaluation criteria be integrated? Which (mis)perceptions are inherent in an integral evaluation? What are the preferences of different stakeholder groups?	X	X		X
Integrated risk management (IRM)	How can/shall I cope with uncertainty? Which of a set of different alternatives are the least risky ones?	X	X		
Life cycle assessment (LCA)	How can the main environmental impacts (on a global level) be evaluated?	X	XX		
Bioecological potential analysis (BEPA)	How can the bioecological quality and potential of a case site be evaluated?		XX	X	
(C) Case development and transition methods					
Mediation: Area development negotiations (ADN)	What causes the conflicts among the principal-agents/key players of the case? Which (mis)perceptions do the case agents have? How can we attain Paretooptimal solutions?		X	X	XX
Future workshops	Which ideas may guide the questions: What can be? What ought to be?			XX	X
(D) Case study team methods					
Experiential case encounter	What does the case look like from the case member's perspective?			XX	X
Synthesis moderation	How can I optimize teamwork to improve the synthesis process? How can I find the right method of synthesis?			X	X

48 All methods are presented and discussed in detail in Scholz & Tietje (2002).

In Table 2, *X* indicates that this type of knowledge integration is established by an embedded case study method, while *XX* indicates that such integration is strongly established by the method.

C. New Frontiers for Science–Society Cooperation

This section discusses how theory-practice or science-society cooperation may continue to evolve. The first part presents a review of how, after nearly two centuries in their 'ivory towers', many scientists are now switching to problem-oriented, Mode 2 science, focusing on real-world problems. The constraints under which ideal transdisciplinary processes can take place are also discussed. The second part elaborates, from an inner-science perspective, on how transdisciplinarity can become a third mode of research, complementing disciplinary and interdisciplinary research. Thirdly, knowledge integration is distinguished from a normal and from a post-normal perspective. The fourth part presents a discussion on discuss how the stance of realism enables scientists to evaluate the quality of scientific assertions of causation, allowing verification of hypotheses.

I. Mode 2: Bringing Science to Society

During most of the past two centuries, the principle of the division of labour by disciplinary differentiation as well as by specialisation at universities has been dominant. To fulfil the goals of science and engineering disciplines to generate consistent and cohesive theories and methods, knowledge production at universities was intended to be academic, free, curiosity-driven, socially and politically neutral, and shaped by specialty and cryptic language. This type of science has been called Mode 1.[49] However, only a relatively small number of universities – primarily 'top' Western European and North American ones – came close to realising this traditional 'ideal'. As a consequence, research came to be seen as an isolated, elitist endeavour, conducted from an ivory tower.

As Gibbons, Nowotny and other proponents of the 'new production of knowledge' sociology proposed,[50] the role of the university changed dra-

49 Gibbons et al. (1994).
50 Gibbons (1999, 2000); Gibbons et al. (1994); Nowotny et al. (2001).

matically in the 1970s, taking on new aspects that went far beyond a narrow, elitist perspective: "[T]he modern university has become a hybrid institution, with multiple and sometimes incommensurable missions."[51]

Universities became an important participant in and driver of industry and regional development. Today, this holds true not only for top universities but even for those in second or third ranking. Already in 1968, about seven million students (43% within the 18–21 age group) were enrolled in institutions of higher learning in the United States.[52] Some countries endeavour to have more than half of their youth earn a university degree. For instance, in Germany, the number of universities increased from 34 in 1949 (25 in West Germany and nine in East Germany) to 350 in 2000.[53] Many former vocational training institutions in remote areas became universities of applied sciences. Although traditionally operating under the label *application and development*, they are moving towards the label of *research*, cooperating with local business and administration on regional developmental problems. However, the production of knowledge has also changed at the top universities. Scientific and technical work is increasingly performed by temporary teams dealing with specific, real-world problems rather than with theory:[54]

> Mode 2 science and technology includes cognitive science, computing, environment studies, biotechnology and aviation. It [Mode 2] is non-academic in the sense that its ties are with society and social issues. Society determines which problems are to be explored and resolved.

According to Gibbons et al.,[55] Mode 2 science provides a new epistemology and asks for a rethinking of science. Mode 2 proponents look at four principles that govern the new form of sciences research:[56]

- The coevolution of science and society
- Contextualisation
- The production of socially robust knowledge, and
- The construction of narratives of expertise.

Such research brings science out of the ivory tower to work with industry, government and laypeople in order to generate socially robust knowledge,

51 Scott (2007:214).
52 Ben-David (1974/1981).
53 Kehm (2004).
54 Shinn (2005:742–743).
55 Gibbons et al. (1994).
56 Gibbons (1999:3).

or sociotechnically robust solutions. At the same time, scientists can use data from the narrative of experiential expertise which emerges from transdisciplinary processes for knowledge integration and theory-building. This will probably operate at all levels: from small, regional colleges to universities which operate globally. Mode 2 shares commonality with the Zurich 2000 definition of transdisciplinarity, and Gibbons et al. state that "Mode 2 is transdisciplinary".[57] Scientists are required to enter into open theory-practice discourses, which require them to cope with complexity and contextualisation. Here, they meet the following situation:[58]

> Collective narratives of expertise need to be constructed to deal with the complexity and the uncertainty generated by this fragmentation. … Experts must respond to issues and questions that are never merely scientific and technical, and must never address audiences that only consist of other experts.

II. Transdisciplinarity as a Third Type of Research

Based on the views outlined above, it is purported that transdisciplinarity becomes, or should become, a third form of academic activity. It is proposed here that many problems ask for knowledge of the disciplinary, interdisciplinary and transdisciplinary type.

At least four arguments supporting this proposal are evident. The first is that of disciplinary communities serving as a clearing-house. Secondly, there is the social contamination of science, which is closely related to the freedom of research. Two additional reasons relate to differentiating between disciplines, and distinguishing between scientific causation and non-scientific causation, as follows:[59]

> Many antidifferentiationists refuse cognitive and social differentiation, and beyond. They deny the division between nature and culture, science and society, science and technology, and between research and enterprise.

Specifically, the third and fourth arguments are described here.

It is considered problematic not to distinguish between knowledge generated in practice, and knowledge generated through scientific processes. An important issue related to the third argument is that, in addition, sciences

57 Gibbons et al. (1994:11).
58 Gibbons (1999:C83).
59 Shinn (2005:744).

include different rationales in reasoning and validation. There are, for instance, different reference schemes for validation, with practical efficacy on the one side and scientific coherence on the other.

An example of differentiating and relating different types of knowledge is provided in area development negotiations,[60] when the science-based assessment (which relies on disciplinary data and methods) is compared with one based on stakeholder judgments. Without doubt, there are different epistemics at work in these different evaluations.

The current study advocates against abandoning the divisions between the modes of thought of science/theory and society/practice, as well as between different disciplines. Transdisciplinary processes require knowledge integration, both for quantitative and qualitative knowledge, for instance, intuitive versus quantitative knowledge (Table 2). An interesting argument against the antidifferentiationist approach, which partly underlies Mode 2 thinking, is that the abandonment of the differentiation between and among science causation and social-agent causation finally pulls everything to pieces. This has been pointed out in the following statement: "The New Production of Knowledge [i.e. the variant of Mode 2, as suggested by Gibbons et al., 1994] posits atomistic learning and social interaction."[61]

III. Key Messages

- Transdisciplinary research does not (and should not) substitute disciplinary and interdisciplinary research, but complements these types of research. It is a third mode of scientific activity that is based on transdisciplinary processes.
- Transdisciplinarity should avoid antidifferentiationist approaches, at least with respect to two dimensions: firstly, the different rationales that are at work in the intuitive, experience-based judgments of practical experts; and secondly, the different types of causation and statements inherent in different sciences. Also, the specific role of individuals is of relevance as regards their reconstruction and evaluation.

60 Scholz (2011:382–384).
61 Shinn (2005:744).

Knowledge integration is key to transdisciplinarity. Such integration should acknowledge the different epistemics from various participants, and is best carried out using method-driven procedures (see Table 2).

References

Almond, Gabriel A., 2000, The Study of Political Culture, in: Crothers, Lane and Charles Lockhart (Eds)*, Culture and Politics*, New York, Palgrave MacMillan.

Bell, Simon & Stephen Morse, 2010a, Rich Pictures: A Means to Explore the 'Sustainable Mind'?, *Sustainable Development* 21(1), 30–47.

Bell, Simon & Stephen Morse, 2010b, Triple Task (TT) Method: Systemic, Reflective Action Research, *Systemic Practice and Action Research* 23(6), 443–452.

Ben-David, Joseph, 1974/1981, *Trends in American Higher Education*, Chicago, The University of Chicago Press.

Blättel-Mink, Birgit & Hans Kastenholz, 2005, Transdisciplinarity in Sustainability Research: Diffusion Conditions of an Institutional Innovation, *Journal of Sustainability and World Ecology* 12(1), 1–12.

Burger, Paul & Rainer Kamber, 2003, Cognitive Integration in Transdisciplinary Science: Knowledge as a Key Notion, *Issues in Integrative Studies* 21, 43–73.

Checkland, Peter, 1981, *Systems Thinking, Systems Practice*, Chichester, Wiley and Sons.

Checkland, Peter & Jim Scholes, 1990, *Soft Systems Methodology in Action*, Chichester, Wiley and Sons.

Checkland, Peter, 2000, Soft Systems Methodology: A Thirty Year Retrospective, *Systems Research and Behavioral Science* 17(1), S11–S58.

Cornwall, Andrea & Rachel Jewkes, 1995, What is Participatory Research?, *Social Science & Medicine* 41(12), 1667–1676.

De Freitas, Lima D., Edgar Morin & Basarab Nicolescu, 1994, Charter of Transdisciplinarity, Unpublished paper presented at the Convento da Arrabida, November 1994. [The Charter of Transdisciplinarity is available at http://www.inters.org/Freitas-Morin-Nicolescu-Transdisciplinarity, last accessed 23 April 2013.]

Funtowicz, Silvio O. & Jerome R. Ravetz, 1993, Science for the Post-Normal Age, *Futures* 7(25), 735–755.

Funtowicz, Silvio O. & Jerome R. Ravetz, 2008, Values and Uncertainties, in: Hirsch Hadorn, Gertrude, Holger Hoffmann-Riem, Susette Biber-Klemm, Walter Grossenbacher-Mansuy, Dominique Joye, Christian Pohl, Urs Wiesmann & Elisabeth Zemp (Eds), *Handbook of Transdisciplinary Research: A Proposition by the Swiss Academies of Arts and Sciences*, Heidelberg, Springer.

Gibbons, Michael, Camille Limoges, Helga Nowotny, Simon Schwartzman, Peter Scott & Martin Trow, 1994, *The New Production of Knowledge*, London, Sage.

Gibbons, Michael, 1999, Science's New Social Contract with Society, *Nature* 402(6761), C81–C84.

Gibbons, Michael, 2000, Changing Patterns of University-industry Relations, *Minerva* 38(3), 352–361.

Gibbons, Michael & Helga Nowotny, 2001, The Potential of Transdisciplinarity, in: Thompson Klein, Julie, Walter Grossenbacher-Mansuy, Rudolf Häberli, Alain Bill, Roland W. Scholz & Myrtha Welti (Eds), *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society, An Effective Way for Managing Complexity*, Basel, Birkhäuser.

Giri, Ananta K., 2011, The Calling of a Creative Transdisciplinarity, *Futures* 34(1), 103–115.

Häberli, Rudolf, Alain Bill & Walter Grossenbacher-Mansuy, 2001, Synthesis, in: Thompson Klein, Julie, Walter Grossenbacher-Mansuy, Rudolf Häberli, Alain Bill, Roland W. Scholz & Myrtha Welti (Eds), *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society: An Effective Way for Managing Complexity*, Basel, Birkhäuser.

Hellier, Augustine, Adrian C. Newton & Susana O. Gaona, 1999, Use of Indigenous Knowledge for Rapidly Assessing Trends in Biodiversity: A Case Study from Chiapas, Mexico, *Biodiversity and Conservation* 8(7), 869–889.

Hirsch Hadorn, Gertrude, Susette Biber-Klemm, Walter Grossenbacher-Mansuy, Holger Hoffmann-Riem, Dominique Joye, Christian Pohl, Urs Wiesmann & Elisabeth Zemp, 2008, The Emergence of Transdisciplinarity as a Form of Research, in: Hirsch Hadorn, Gertrude, Holger Hoffmann-Riem, Susette Biber-Klemm, Walter Grossenbacher-Mansuy, Dominique Joye, Christian Pohl, Urs Wiesmann & Elisabeth Zemp (Eds), *Handbook of Transdisciplinary Research: A Proposition by the Swiss Academies of Arts and Sciences*, Heidelberg, Springer.

Hoffmann, Volker, Angelika Thomas & Alexander Gerber (Eds), 2009, *Transdisziplinäre Umweltforschung: Methodenhandbuch*, München, Oekom.

Jaeger, Jochen & Martin Scheringer, 1998, Transdisziplinarität: Problemorientierung ohne Methodenzwang, *GAIA: Ecological Perspectives in Science, Humanities, and Economics* 7(1), 10–25.

Jantsch, Erich, 1972, *Towards Interdisciplinarity and Transdisciplinarity in Education and Innovation*, Paris, Organisation for Economic Co-operation and Development.

Jungk, Robert & Norbert R. Müllert, 1994, *Zukunftswerkstätten: Mit Phantasie gegen Routine und Resignation*, München, Heyne.

Kehm, Barbara M., 2004, Hochschulen in Deutschland: Entwicklung, Probleme und Perspektiven, *Aus Politik und Zeitgeschichte* 25, 6–17.

KfC/Knowledge for Cimate, 2008, *Executive Summary of the Dutch National Research Program*, Utrecht, Knowledge for Climate.

Kruse, Natalie, Freida M. Behets, Georgina Vaovola, Gillian Burkhardt, Texina Barivelo, X. Amida & Gina A. Dallabetta, 2003, Participatory Mapping of Sex Trade and Enumeration of Sex Workers Using Capture–recapture Methodology in Diego-Suarez, Madagascar, *Sexually Transmitted Diseases* 30(8), 664–670.

Krütli, Pius, Thomas Flüeler, Michael Stauffacher, Arnim Wiek & Roland W. Scholz, 2010, Technical Safety vs. Public Involvement? A Case Study on the Unrealized Project for the Disposal of Nuclear Waste at Wellenberg (Switzerland), *Journal of Integrative Environmental Sciences* 7(3), 229–244.

Meppem, Tony & Roderic Gill, 1998, Planning for Sustainability as a Learning Concept, *Ecological Economics* 26(2), 121–137 (17).

Mieg, Harald A., Peter Hübner, Michael Stauffacher, Marianne E. Balmer & Sandro Bösch (Eds), 2001, *Zukunft Schiene Schweiz 2 – Ökologisches Potenzial des SBB-Bahngüterverkehrs für die Region Zugersee, ETH-UNS Fallstudie 2000*, Zürich, Ruegger.

Mittelstrass, Jürgen, 1996, Transdisziplinarität, in: Mittelstrass, Jürgen (Ed.), *Enzyklopädie Philosophie und Wissenschaftstheorie*, Band 4, Stuttgart, Metzler.

Nicolescu, Basarab, 2002, *Manifest of Transdisciplinarity*, Albany, State University of New York.

Nowotny, Helga, Peter Scott & Michael Gibbons, 2001, *Re-thinking Science: Knowledge and the Public in an Age of Uncertainty*, London, Polity Press.

Pohl, Christian, 2008, From Science to Policy Through Transdisciplinary Research, *Environmental Science and Policy* 11(1), 46–53.

Reeger, Barbara J. & Joske F.G. Bunders, 2009, *Knowledge Co-creation: Interaction between Science and Society – A Transdisciplinary Approach to Complex Societal Issues*, Den Haag, Raad voor Ruimtelijk, Milieu- en Natuuronderzoek.

Schnelle, Eberhard, 1979, The Metaplan-method: Communication Tools for Planning and Learning Groups, *Metaplan Series 7*, Quickborn, Metaplan.

Scholz, Roland W. 1998, Umweltforschung zwischen Formalwissenschaft und Verständnis: Muss man den Formalismus beherrschen, um die Formalisten zu schlagen?, in: Daschkeit, Achim & Winfried Schröder (Eds), *Umweltforschung quergedacht: Perspektiven integrativer Umweltforschung und -lehre*, Berlin, Springer.

Scholz, Roland W., 2000, Mutual Learning as a Basic Principle of Transdisciplinarity, in: Scholz, Roland W., Rudolf Häberli, Alain Bill & Myrtha Welti (Eds), *Transdisciplinarity: Joint Problem-Solving among Science, Technology and Society. Workbook II: Mutual Learning Sessions*, Zürich, Haffmans Sachbuch.

Scholz, Roland W., 2011, *Environmental Literacy in Science and Society: From Knowledge to Decisions*, Cambridge, Cambridge University Press.

Scholz, Roland W. & David Marks, 2001, Learning about Transdisciplinarity: Where Are We? Where Have We Been? Where Should We Go?, Thompson Klein, Julie, Walter Grossenbacher-Mansuy, Rudolf Häberli, Alain Bill, Roland W. Scholz & Myrtha Welti (Eds), *Transdisciplinarity: Joint Problem Solving among Science, Technology, and Society, An Effective Way for Managing Complexity*, Basel, Birkhäuser.

Scholz, Roland W. & Michael Stauffacher, 2007, Managing Transition in Clusters: Area Development Negotiations as a Tool for Sustaining Traditional Industries in a Swiss Prealpine Region, *Environment and Planning* A39(10), 2518–2539.

Scholz, Roland W. & Olaf Tietje, 2002, *Embedded Case Study Methods: Integrating Quantitative and Qualitative Knowledge*, Thousand Oaks, Sage.

Scholz, Roland W., Harald A. Mieg & Jenny Oswald, 2000, Transdisciplinarity in Groundwater Management: Towards Mutual Learning of Science and Society, *Water, Air, and Soil Pollution* 123(1–4), 477–487.

Scholz, Roland W., Sandro Bosch, Harald A. Mieg & Jörg Stünzi (Eds), 1997, *Zentrum Zürich Nord: Stadt im Aufbruch: Bausteine für eine nachhaltige Stadtentwicklung*, Zürich, vdf Hochschulverlag.

Scholz, Roland W., Sandro Bösch, Michael Stauffacher & Jenny Oswald (Eds), 2001, *Zukunft Schiene Schweiz 1: Ökoeffizientes Handeln der SBB*, Zürich, Ruegger.

Scholz, Roland W., Theo Koller, Harald A. Mieg & Corinne Schmidlin, 1995, *Perspektive "Grosses Moos" – Wege zu einer nachhaltigen Landwirtschaft*, Zürich, vdf Hochschulverlag.

Scholz, Roland W., Michael Stauffacher, Sandro Bösch & Pius Krütli, 2004, *Mobilität und zukunftsfähige Stadtentwicklung: Freizeit in der Stadt Basel*, Zürich, Ruegger und Pabst.

Scholz, Roland W., Michael Stauffacher, Sandro Bösch & Pius Krütli, 2005, *Nachhaltige Bahnhofs- und Stadtentwicklung in der trinationalen Agglomeration: Bahnhöfe in der Stadt Basel*, Zürich, Ruegger.

Scholz, Roland W., Michael Stauffacher, Sandro Bösch & Arnim Wiek (Eds), 2002, *Landschaftsnutzung für die Zukunft: Der Fall Appenzell Ausserrhoden*, Zürich, Ruegger und Pabst.

Scholz, Roland W., Sandro Bösch, Theo Koller, Harald A. Mieg & Jörg Stünzi (Eds), 1996, *Industrieareal Sulzer-Escher Wyss: Umwelt und Bauen – Wertschöpfung durch Umnutzung*, Zürich, vdf Hochschulverlag.

Scholz, Roland W., Daniel J. Lang, Arnim Wiek, Alexander I. Walter & Michael Stauffacher, 2006, Transdisciplinary Case Studies as a Means of Sustainability Learning: Historical Framework and Theory, *International Journal of Sustainability in Higher Education* 7(3), 226–251.

Scholz, Roland W., Micahel Stauffacher, Sandro Bösch, Pius Krütli & Arnim Wiek, 2007, *Entscheidungsprozesse Wellenberg – Lagerung radioaktiver Abfälle in der Schweiz. ETH-UNS Fallstudie 2006*, Zürich, Rüegger.

Scott, Peter, 2007, From Professor to 'Knowledge Worker': Profiles of the Academic Profession, *Minerva* 45(2), 205–215.

Sen, Amartya, 1999, *Development as Freedom*, New York, Knopf.

Shinn, Terry, 2005, New Sources of Radical Innovation: Research-technologies, Transversality and Distributed Learning in a Post-industrial Order, *Social Science Information* 44(4), 731–764.

Swedberg, Richard, 1990, *Economics and Sociology: Redefining Their Boundaries: Conversations with Economists and Sociologists*, Princeton, Princeton University Press.

Thompson Klein, Julie & William H. Newell, 1997, Advancing Interdisciplinary Studies, in: Gaff, Jerry G., James L. Radcliff & Associates (Eds), *Handbook of the Undergraduate Curriculum*, San Francisco, Jossey-Bass.

Van de Kerkhof, Marleen & Pieter Leroy, 2000, Recent Environmental Research in the Netherlands: Towards Post-normal Science?, *Futures* 32(9–10), 899–911.

Waert, Spencer, 2003, *The Discovery of Global Warming*, Cambridge, MA, Harvard University Press.