African Journal of Science, Technology, Innovation and Development
Vol. 2, No. 1, 2010
pp. 114-137

Science for the Future: Challenges and Methods for Transdisciplinary Sustainability Research

Martina Schäfer,* Dörte Ohlhorst,** Susanne Schön***
and Sylvia Kruse****

Abstract

Sustainability research is aimed at meeting the challenge of dealing with important societal problems related to the 'metabolic' processes between society and nature in a global context. Besides generating knowledge about the characteristics and dynamics of the complex processes involved (e.g. climate change, loss of biodiversity, increasing poverty and hunger), it should also contribute to normative knowledge about how to evaluate these processes and develop strategies for social change towards sustainability. An interdisciplinary composition of research teams is necessary to deal with the complexity of sustainability problems. The normative questions and the need for decisions to be made in situations of uncertainty additionally call for a transdisciplinary research design, involving actors from the life-world as equal partners. The process of integrating knowledge from different disciplines as well as from the life-world is a great challenge which needs to be met through methodological innovation. This article introduces constellation analysis as a methodological approach for bridging different knowledge claims, drawing on two case studies to demonstrate its application.

* Center for Technology and Society, Technische Universität Berlin, Berlin, Germany. Email: schaefer@ztg.tu-berlin.de

** Center for Technology and Society, Technische Universität Berlin, Berlin, Germany. Email: ohlhorst@ztg.tu-berlin.de

*** Inter 3 – Institute for Resource Management, Berlin, Germany. Email: schoen@inter3.de

**** Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland: Email: sylvia.kruse@wsl.ch

Keywords: Interdisciplinarity, Transdisciplinarity, Sustainability research, Knowledge integration, Constellation analysis

JEL Classification: O18, Q01, Q56

1. Introduction

With the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, the concept of sustainable development – bringing together questions of social justice with environmental issues – has gained importance in international politics. Based on these political processes, a new field of research has developed within the last decade: sustainability research. Sustainability problems are characterized by being globally interlinked, complex, synergetic, cumulative, and highly dynamic, often marked by non-linear causal chains and significant time lags between causes and effects in the interplay between social and natural systems (Siebenhüner, 2004: 76). Due to the complex problems and the need to develop strategies for a rather deep social and ecological transformation of society, sustainability research is often organized as inter- and transdisciplinary research. This research type faces the challenge of integrating knowledge and methods from different scientific disciplines and of integrating both life-world and scientific knowledge.

Sustainability research can be understood as being part of a transformation towards a new mode of knowledge production, called "mode 2" (Nowotny et al., 2001; Gibbons and Nowotny, 2000, Gibbons et al., 1994), in contrast to disciplinary science ("mode 1"). Science of this type acknowledges the appearance during the last few decades of societal problems of a new quality, which cannot be dealt with adequately solely via disciplinary science (Schmidt and Grunwald, 2005; Mittelstraß, 2005; Jahn, 2003; Lange, 2003; Bechmann, 2000; Brand, 2000). Other prominent fields for inter- and transdisciplinary approaches are health, risk, environmental and innovation research (Pohl and Hirsch-Hadorn, 2008; Schön et al., 2007).

The basic demand of inter- and transdisciplinary approaches is to integrate different perspectives and knowledge successfully throughout the whole research process (Pohl and Hirsch-Hadorn, 2008). Although some scholars have tested methods and tools for sustainability research over the last years (Schophaus et al., 2004; von Blanckenburg et al., 2005; Pohl and Hirsch-Hadorn, 2008), innovative methods in this domain are not yet sufficiently explored. The need for a middle-range concept which is able to bridge different areas of expertise and enable the understanding between persons with different scientific and professional backgrounds, rationalities and logics of action has led to the development of constellation analysis at the Center of Technology and Society of the Technische Universität Berlin (Schön et al., 2007)[1]. In this paper we introduce constellation analysis as a bridging concept, demonstrate its applicability for different purposes and conclude how it could be used for sustainability and innovation research in industrialized and emerging countries.

2. Characteristics of sustainability research and methodological challenges

(a) Characteristics of sustainability research

Sustainable Development is a political concept which is based on the normative premises of intra- and intergenerational justice and compatibility with the limitations of natural resources. The operationalization of these premises in concrete guidelines for future development strategies is a controversial issue in society as well as in science. The understanding of 'sustainable development' therefore has to be clarified in each process of sustainability research, the scientist being only one of the societal actors who position themselves with their interests and values in a field of conflicts. Since problem definition in sustainable research is directly linked to normative values, science alone is not competent enough and legitimised to realize research and draw on recommendations without consulting societal actors (Nölting et al., 2004; Schäfer, 2007).

Further, sustainability research is characterized by taking up life-world problems in the intersection of society and nature which urgently call for political action and coping strategies even if the knowledge available about causal interrelations and the effects of interventions is highly uncertain (Bechmann, 2000).

A methodological consequence of these characteristics is the necessity for the integration of knowledge from different disciplines as well as the systematic integration of life-world knowledge (Becker and Jahn, 2006: 292-308).

Brand (2000: 24) describes the function of inter- and transdisciplinary sustainability research as follows:

> Transdisciplinary sustainability research aims to contribute to the solution of different problems of sustainable development. The premise is that these solutions cannot be worked out alone by science and not by highly specialized disciplines. On the contrary, sustainability problems partly result from the dynamics of scientific, technical and societal processes of differentiation. However, solutions also cannot be found without highly specialized science – but only through new, problem-oriented, interdisciplinary

connections being created.

In sustainable or transdisciplinary research a differentiation is made between three types of knowledge that are generated (Cass/ProClim, 1997; Maier Begré and Hirsch Hadorn, 2002; Nölting et al., 2004; Pohl and Hirsch-Hadorn, 2007):

- *Systems knowledge:* about the characteristics and dynamics of processes and the interconnections between ecological, economic, social and cultural aspects;
- *Normative or target knowledge*: helps to evaluate the sustainability of societal transformation; and
- *Transformation knowledge:* helps to develop strategies for societal transformation process.

All three types of knowledge are linked with each other and have to be analyzed interdependently (Hirsch-Hadorn et al., 2002: 15). There are different reasons for integrating non-scientific or popular knowledge into the generation of each of these types of knowledge. Regarding the generation of systems knowledge, exchange with practitioners allows insight into interconnections and limitations that can only be experienced by being an actor in the field concerned. Including other forms of knowledge also makes it easier to obtain an impression of the different scales (local, regional, national, global) and the multiple, interactive, and cumulative character of certain problems (Siebenhüner, 2004: 77).

As mentioned above, the need for integration of different societal perspectives seems especially evident concerning the generation of normative or target knowledge. Scientific research can help to identify different interests and moderate the process of discussing transformation goals, but it cannot define normative premises on its own. Defining critical loads or threshold values, evaluating risks, dealing with uncertainty, choosing transformation goals and indicators – all these steps are based on normative decisions, which imply conflicts of interests and values. Transformation goals only have a chance of being implemented if they are accepted by those who will be affected. Acceptance requires integrating these actors in the transformation process at an early stage (Brand, 2000: 20).

Concerning transformation knowledge, exchange with practitioners is essential for the development of solutions or strategies that are context-specific and will be relevant in practice. The success chances for necessary changes improve if those groups affected are not only integrated into the definition of transformation goals, but also into the construction of transformation strategies and measures (ibid.).

(b) Methodological challenges of inter- and transdisciplinary research

Interdisciplinary research teams have to integrate different methodological approaches as well as disciplinary knowledge related to their specific research problems. At the bottom, this cognitive integration process involves linking empirical data and theoretical concepts from very different backgrounds, that is from social and natural sciences (Nölting et al., 2004). One of the main difficulties for interdisciplinary cooperation is to differentiate between the different disciplines, their technical terms and languages. Researchers perceive this very time intensive process as the main difficulty and even barrier to interdisciplinary research (Lowe and Philippson, 2009; Böhm, 2006; Bromme, 1999; Klein, 1996).

The problems of mutual understanding are even more evident in transdisciplinary projects which aim at integrating 'life-world' knowledge throughout the research process. Practitioners and scientists act on the basis of very different rationalities and logics of action - besides not being groups of homogeneous actors. While, for example, the scientists are interested in in-depth analyses which allow reliable conclusions, practitioners many times are obliged to take short-term action. They quickly need advice which can easily be transformed into concrete strategies. Limoges (1993: 420) states that each of the researchers and practitioners locates the problem in an alternative "world of relevance". This diversity in perspectives must be taken into account while identifying and structuring the problem and while developing and testing means to deal with it. Several authors agree that the first step in mutual learning and integration is to acknowledge the diversity of perspectives and to explore and clarify their differences (Giri, 2002; Loibl, 2005; Loibl, 2006; MacMynowski, 2007).

Pohl and Hirsch-Hadorn (2007) differentiate three phases of a transdisciplinary research process: a) problem identification and structuring; b) problem analysis; and c) bringing results to fruition. Furthermore, they have introduced four principles for carrying out transdisciplinary research: a) reduce complexity by specifying the need for knowledge and those involved; b) achieve effectiveness by contextualization; c) achieve integration through open encounters; and d) develop reflexivity through recursiveness.

The first principle-- specifying the need for knowledge -- implies deciding which research questions need to be addressed by a project and determining the corresponding conditions. To this end, it is necessary to find out what kind of systemic perception underlies a project, what normative targets it has set itself, and what potential societal transformations it aims at. The second principle states that impact-related contextualisation of a project consists in making the research results accessible to those concerned. For this aim, it is essential to reformulate the results differently for specific target groups. The third principle of integration by being open to encounters frames the aspect we already mentioned above: It implies perceiving one's own perspective as only one among several others, and accepting other views as potentially just as relevant as one's own. Only thus can constructive discussions about the potential of various perspectives to contribute to a common undertaking take place and be further developed. The forth principle, recursiveness, means that the research process is shaped in such a way that theory and methods are repeatedly tested by applying them to practice and that underlying assumptions can be modified if they are found to be inadequate. According to Pohl and Hirsch-Hadorn (2007) such a recursive design is a pragmatic way to prevent a project from becoming stuck due to uncertainty or the preliminary state of knowledge.

Researchers in this field have to translate the challenges of reducing complexity, contexutalisation, integration and recursiveness into the formulation of concrete methods. Over the past decade, a more intense reflection on success factors and adequate methods and tools for inter- and transdisciplinary cooperation processes has emerged (Mogalle, 2001; Schäfer and Boeckmann, 2004; Schophaus et al., 2004; Strübing et al., 2004; Bergmann et al., 2005; von Blanckenburg et al., 2005; Pfriem et al., 2006; Pohl and Hirsch-Hadorn, 2006; Boeckmann et al., 2007; Pohl and Hirsch-Hadorn, 2008). Many of these publications concentrate on aspects of cooperation management and offer recommendations for an adequate organizational structure of these processes. Others introduce different types of participative tools which allow integrating life-world knowledge (e.g. citizen juries, scenario workshops, future conferences) or deal with conflicts concerning transformation strategies (e.g. mediation, consensus conferences). Up till now, however, few methods have been developed which facilitate obtaining insight into and allowing the structuring of the perspectives of actors with different backgrounds – be it different disciplines or scientific versus life-world backgrounds.

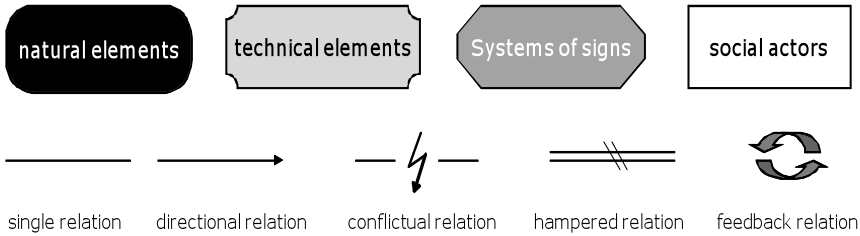
3. Constellation analysis: a bridging concept for inter- and transdisciplinary research

To meet some of the demands for carrying out inter- and transdisciplinary research, constellation analysis was developed as a bridging concept for mutual understanding between different disciplines and between science and life-world actors (Schön et al., 2007). Here, a bridging concept means an approach comprising several analytical categories which different disciplines can relate to.

Core elements of constellation analysis

The complex problems treated in sustainability and innovation research are understood as constellations which are characterized by interactions between different factors, dynamics and contexts. A constellation is mapped by an interdisciplinary or transdisciplinary research team starting from its central elements. Adding new elements, research team members from different disciplines and/or lay experts judge the relevance of successive elements proposed, initiating a discursive mapping process. The team agrees on a common interpretation of the relevant elements and relations within the constellation and the influences between them. Constellations consist of different types of elements, differentiating social actors, natural elements, technical elements and systems of signs. Social actors can be individuals as well as social groups that are actively involved in the decision-making process. Technical elements include all technical artifacts. Natural elements characterize substances and resources, animals and plants as well as other natural phenomena. Systems of signs include ideas, concepts, ideologies, laws, communicative acts and images. Taking into consideration early actor-network theory concepts (Latour, 1987), the central focus of this method is treating the heterogeneous elements as being equal. This emancipated consideration of the elements allows a non-hierarchical interdisciplinary cooperation which does not differentiate in terms of 'leading' and 'auxiliary disciplines'.

The four types of elements and the relations between them are characterized by symbols:

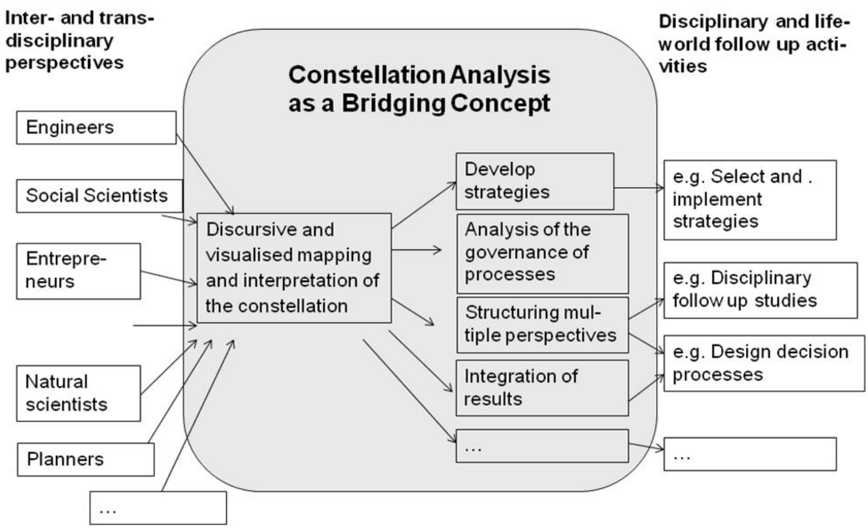


After identifying the central elements, the interrelations between them are analyzed and mapped. This step obliges the actors involved to refer to each other's perspective. Clarification of the relations between the elements is necessary to be able to understand the structure and logic of a constellation. The next step consists in describing the dynamics of a constellation. The key element of the method is the visualization of the constellation in the form of a graphic image. Transforming an inter- and transdisciplinary discussion into a graphic representation enhances mutual understanding by relating different perspectives to each other and clarifying points of consensus and dissent. Visualizing complex constellations makes it easier to depict them in several steps and to analyze and discuss them collaboratively, both within the research team and with lay-actors. Visualization therefore supports language in the process of mutual understanding as an important supplementary medium.

So far, constellation analysis has been implemented with different objectives: (a) mapping of the diversity of perspectives; (b) development of strategies on the basis of a constellation mapping; (c) analysis of the implementation and the impact of policy measures on the structure of a constellation over a longer period of time; and (d) integration of results within an interdisciplinary research project.

All of these objectives have in common that the step of constellation mapping was the prerequisite for inter- and transdisciplinary analysis by providing structuring and systematisation. Figure 1 illustrates the function of the constellation analysis as a bridging concept for mutual understanding.

Figure 1: Constellation analysis as a bridging concept



Source: Translation from Schön *et al*. (2007).

Application of constellation analysis: Two case studies

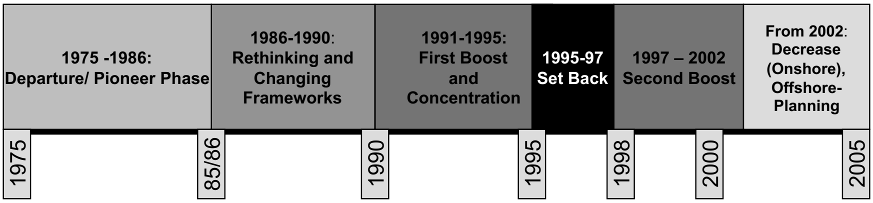
The following sections introduce two case studies applying constellation analysis in sustainability research, featuring the main characteristics of interdisciplinary and transdisciplinary sustainability research. The first focuses on the development of the wind energy sector in Germany and tackles the implementation and impact of technological innovation and policy measures on the structure of a constellation over a period of thirty years. The second case study investigates the diversity of perspectives on flood management in the Middle Elbe Region in Germany, wherein the views of different actor groups involved in flood management are mapped focusing on values and rationales.

Case 1 - The German wind energy sector: mapping an innovation biography

The German wind energy sector has seen rapid growth during the last 40 years and was marked by a dynamic process of innovation, with Germany having become the world's leading wind energy producer. A research project[2] proceeded from the hypothesis that, in the course of the innovation of wind energy, both the network structure of decision makers and the application of technology shifted (Ohlhorst, 2009; Bruns et al., 2008). It was assumed that technical and natural elements are closely linked to institutional and social developments and that this heterogeneous constellation has been permanently reorganized.

The relations between the main elements and the impact of regulation measures were investigated employing an inter- and transdisciplinary research process. The core agents and the main forces of change were identified and their characteristics described. The mapping process was guided by the two questions: Firstly, which decision makers and interests influenced the innovation process? Secondly, do other aspects, such as technology, economic, ecologic, social, institutional or natural conditions, play an important role? By mapping constellations of different development phases of the sector, the study was able to analyze whether it was the role of the actors or other elements that had changed over the years. The core question was: What conclusions can be drawn from change of these constellations for governing innovation processes?

Figure 2: Phases of the development of the German wind sector



Source: Ohlhorst (2009)

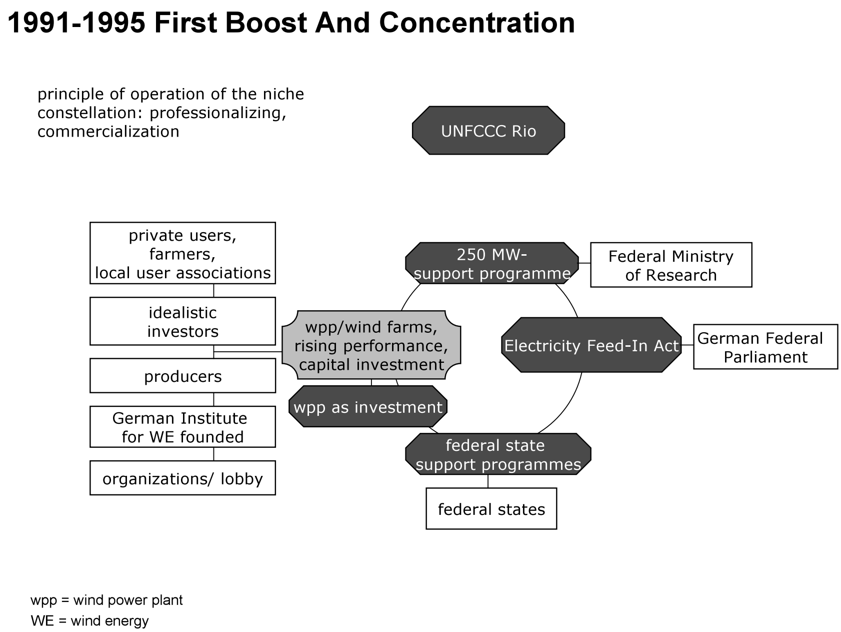
Figure 2 summarizes the development of the German wind energy sector in different phases. The energy sector in the 1970s was dominated by centralized energy suppliers which used fossil energy sources or invested in nuclear energy plants. Motivated by the oil crises and the environmental as well as the anti-nuclear movements the development of the wind energy sector began as a niche. From 1975 to 1986, wind power was generated mainly for private and local requirements, for example by farmers, in small, decentralized plants.

Between 1986 and 1990, in the second phase, there was much change in the field of energy policy and the surrounding conditions. That is, in 1986 the reactor catastrophe of Chernobyl occurred, the Brundtland-report pointed out the limits of growth and created awareness about the problem of climate change. The operator-communities of wind energy producers were growing. That is, at that stage, there were not only single turbines, but also the development of the first wind farms, comprising three or more plants. Substantial support programs and subsidies led to technical progress in the sector. As an external influence, particularly the development of the wind energy sector in Denmark became a role model and, as such, exerted a driving force.

From 1991 until the mid 1990s, an initial 'wind energy boost' occurred in Germany, mainly because of the 'Feed-In Act' for electricity and also because of the governmental '250 MW-support program'. Figure 3 shows the constellation of the wind energy sector in this phase.

Governmental interventions in this phase were embedded in a consistent strategy: The energy markets were opened and liberalized and the national government had important ecological and climate-protection aims. The governmental measures were supported by a broad alliance of actors, some of which had newly entered the constellation: investors, operators, producers, politicians and lobbyists.

Figure 3: Constellation of the energy sector from 1991 to 1995



Source: Ohlhorst (2009)

But the governmental actions were not the only driving forces in this phase, as they interacted with other factors. Wind energy plants became appealing for capital investment. The local operator communities became increasingly differentiated, using their expertise to expand and professionalize. The professionalization of the operator companies was crucial for the wind energy boost in the early 1990s.

In the middle of the 1990s, the fourth phase, Ohlhorst identified a break in the development of wind energy in Germany. The power supply companies and their associations expressed doubts about the conformity of the Feed-In Act with European Union law. One result was an uncertainty for investors and a slump in sales of wind turbines. Simultaneously, the acceptance of wind power plants decreased also because wind turbines got bigger, developing to big industrial installations.

The national governmental initiatives stagnated:

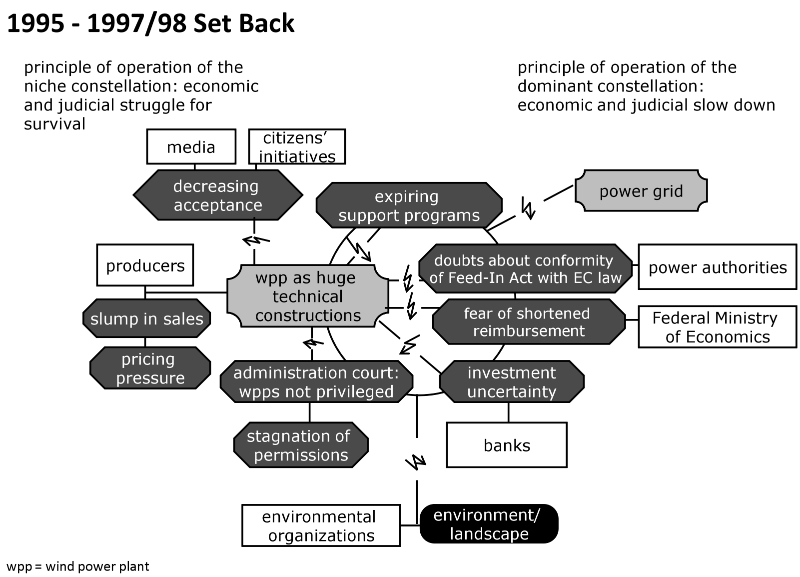
- The support programs expired, and the Feed-In Act was massively attacked by the energy-supply industry. Their representatives intervened with legal measures and claimed that the law did not comply with European Union subsidy regulations.

- The national ministry for economic affairs considered a reduction of the feed-in tariffs.
- The national administration court decided that wind power plants were not to be considered as privileged construction projects in the building law – countering their assessment in the ongoing debate.

The uncertainty increased and affected many actors, such as authorities, banks, investors and producers. There were also technological factors which had a retarding effect: Due to rapid innovation cycles, some of the plants were not well constructed. Since these plants were prone to errors and dysfunction, they harmed the image of the whole technology.

To sum up, the motivations and aims in this phase seemed to be ambivalent and partly contradictory, even on the part of the state actors, so the constellation appears inconsistent.

Figure 4: Constellation of the energy sector from 1995 to 1998



Source: Ohlhorst (2009)

Figure 4 illustrates changes of the constellation in this phase. The last two phases were mapped in a similar way. At the end of the 1990s, a second boost of wind energy deployment started. The European Court of Justice decided that the Feed-In Act complied with European Union law, and wind farms again became attractive for capital investment. The new Feed-In Act, called the 'Renewable Energy Sources Act,' provided long-term feed-in tariffs and planning reliability for the operators. Furthermore, increasing the percentage of renewable energies played a crucial role concerning the political targets in the field of climate protection. The state initiatives responded adequately in providing the means to overcome the obstacles of the preceding phase. However, there were also some unintended impacts of the state measures: In some regions there was an uncontrolled growth of wind power plants and conflicts between different ecological targets (nature protection and climate protection) became more obvious.

In the sixth phase, from 2002 to now, the constellation split into two parts: the onshore and the offshore wind energy sectors. Onshore, wind energy development in Germany has been decreasing. Despite much planning, only a few offshore German wind turbines have been realized in a North Sea wind energy test site.

Employing the process of mapping and analyzing the above constellations, formulated with the help of scientists from different disciplines and actors from the wind sector, several results became evident:

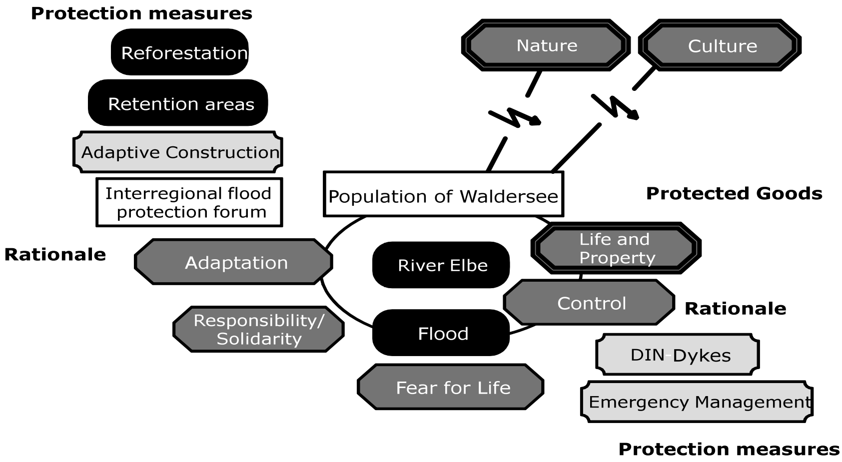
- By visualizing the different perspectives it was possible to get a more detailed picture about the relevant elements and relations. The process of assembling mutual consent about the structure of the problem and its characteristics was supported by mapping the constellations.
- Carrying out the analysis together led to a common understanding of the main influential factors and awareness that successful innovation processes depend on parallel progress being achieved in various dimensions (e.g. technology, social aspects, politics, and favorable surrounding conditions).
- The constellations of different phases showed that the state had changed its interests and aims in the course of the process. The figures made the strategy-change of state actors and institutions perceivable for all actors.
- The analysis showed that different regulatory measures made sense in different parts of the constellation at a given time and level of the innovation process. Used as a scenario instrument, the constellation analysis was able to help in identifying the phases and crucial points for successful governmental action.
- By participating in the analysis, the actors of the wind energy sector were able to understand the sector's 'innovation biography' better, which helped them to draw conclusions for further development processes.
- From a scientific point of view, understanding innovation processes in one sector can be useful for analyzing other sectors (e.g. solar energy, energy from biomass), identifying their commonalities and differences.

Case 2 - Flood management: understanding different perspectives for strategy development

The second case study draws upon a transformation process in flood management in the aftermath of extreme flooding of the Elbe and Mulde rivers in Southeast Germany in August 2002 (Kruse, 2010). After the flood, which had resulted in substantial damage to infrastructure, private houses and agricultural land, all groups of actors stated that there had been mistakes in the past and demanded a change of strategy for flood protection. However, there was no common understanding of what should change and how this change should be brought about. Discourse about the flood and how to react to it quickly became very emotional, and soon the different actors and actor-groups seemed to separate into two camps: those who wanted a change of strategy and to give more space to the river, and those who wanted to achieve more security through technical flood-protection measures. As their positions hardened, it became very difficult to lead a constructive, solution-oriented dialogue.

A research project[3] tried to enhance mutual understanding by mapping the different perspectives on flood-protection strategies in the Federal State of Saxony-Anhalt (Forschungsverbund 'Blockierter Wandel', 2007). A comparison between the different perspectives was intended to illuminate the differences between positions, the nature of real or perceived conflicts and key obstacles to the implementation of flood-protection measures. The constellations are based on qualitative interviews with representatives of all the groups involved in the flood-protection scheme under study. The interviewees tried to clarify what they would consider the main aims of and rationales for flood protection (what they would call the 'right' measures). Within the research project actors like the Authority for Flood Protection of Saxony-Anhalt, several local communities, environmental organisations and the authority for cultural heritage (Kulturstiftung) were interviewed. Based on the interviews and documents, the perspective of each actor group involved in the flood-management discourse was mapped with the help of constellation analysis. The interviewees were then consulted several times in order to discuss the maps and the initial findings. They had the opportunity to revise or change the map, to comment on the visualisation, or express their own interpretation.

Figure 5: The 'Waldersee-Perspective'

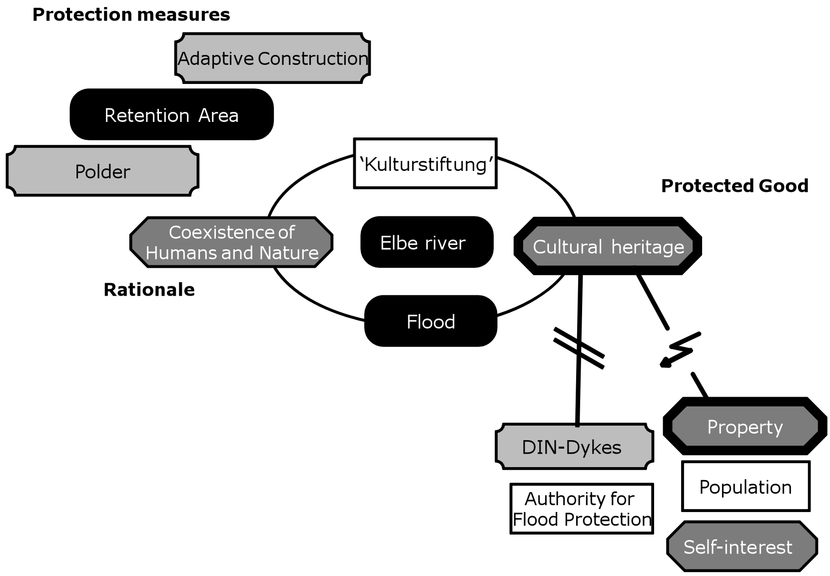


Source: Kruse (2008)

Figures 5 and 6 show perspectives of two different actors concerning possible strategies of preventing floods in the future: The first is one of the communities (Waldersee) which was severely affected by the flood (see Figure 5) and the second the federal authority for the protection of historic buildings and monuments (Kulturstiftung), which is illustrated by Figure 6.

For the population of Waldersee, the primary aim of the protection-measures is to prevent their livelihoods and property from future flooding. They acknowledge that nature and culture are important goods, but if their protection conflicts with the protection of livelihoods and property – which happened in several cases in the restoration and rebuilding of the protective infrastructure – they are seen as subordinate. In the opinion of the Waldersee community, the rationality of flood protection should primarily be to control and regulate flood events through a secure dyke system and improved emergency management. However, adaption to flood events was seen as a back-up strategy, on the assumption that technical means cannot prevent a catastrophe entirely.

Figure 6: Perspective of the *Kulturstiftung* on flood protection measures



Source: Kruse (2008)

The population of Waldersee has introduced a wide range of proposals for future approaches to flood protection. These include both technical protective means, such as dykes and emergency management, and preventive measures, such as reforestation, the creation of retention areas and the initiation of an interregional flood-protection forum.

The perspective of the Kulturstiftung reveals another characteristic of the debate. The Kulturstiftung's main focus is on destructive flood protection measures rather than destructive flood events. Heading the conservation of the UNESCO world cultural heritage site 'Dessau-Wörlitzer Gartenreich' (known as 'The Garden Kingdom of Dessau-Wörlitz'), which lies in the floodplain of the river Elbe, the Kulturstiftung mainly wants to protect its historical intactness. As a result, it has criticised all flood-protection measures that proposed to reinforce, and thus to alter, the ancient dykes, which are designated as historic structures. It also accused the local population of according their property and selfish interests a higher status than the national, common interest in cultural heritage. Furthermore, it insisted that the Authority for Flood Protection ought not to adhere to the standard of dyke restoration in cases of designated historic dyke structures.

According to this body's perspective, flood protection should follow the rationale for the coexistence of humans and nature and should focus on natural flood protection by building polders, widening retention areas and supporting adaptive building strategies.

Figures 5 and 6 outline the perspectives of the Waldersee community and the Kulturstiftung respectively on flood protection measures. Mapping the different perspectives was the first step of the research project. To enhance mutual understanding, the maps of other actors' perspectives were then compared and discussed with the interviewees. During these feedback discussions most of the actors interviewed were very interested in the perspectives of the other actor groups and often exhibited a 'light-bulb' effect: "I never thought they saw it that way!". This was the basis for organizing a workshop bringing the different stakeholders together at one table and facilitating dialogue rather than confronting different positions.

Applying constellation analysis in this project had the following benefits:

- Mapping the main elements and the interrelations between them helped the research team to get a first impression of the constellation as a starting point for transdisciplinary dialogue.
- With the help of this method, it was possible to clarify different perspectives on flood-protection strategies of the actors involved. The graphic representation was a good tool for discussing the different perspectives with the actors in an open and transparent way.
- Comparing the different perspectives was helpful for identifying commonalities and sorting out the crucial points for discussion and mediation. The results of this analytical process could then be used by actors responsible for the design of future flood-protection strategies.

The research project concludes that this way of mapping multiple perspectives can prepare and facilitate dialogues and negotiation processes, which previously have been blocked. It can be a constructive means for reaching a common problem definition, as a first step in conducting participatory negotiation.

4. Conclusions

Constellation analysis has proved to be very helpful for achieving mutual understanding in inter- and transdisciplinary research projects and can be applied with different objectives. The possible applications are discussed along the three phases of transdisciplinary research processes and the four principles which were introduced in Section 2 (Pohl and Hirsch Hadorn, 2007).

We have shown that constellation analysis can be applied with good effects for problem identification and structuring. The graphic representation involved facilitates discussion of participants from different scientific and professional background and helps to structure the problem according to the main elements and their relations. The defined set of elements – technical, natural, social and symbolic – supports the participants in describing 'the whole picture' and inhibits them from holding on to uni-dimensional or incomplete framings of the problem concerned.

The advantages described are also relevant for the second phase of problem analysis. By describing the relations between the elements in detail and identifying conflicting, hampered or feedback relations, systems knowledge is deepened. Interdisciplinary and transdisciplinary dialogue is crucial for a thorough analysis of the problem. Besides identifying the main actors and policy measures which are influential in a constellation – which would be the focus of social-science analysis - it calls attention to the influence and agency of natural and technical elements. On the other hand, engineers and natural scientists, who might focus solely on technical aspects and the limits of natural resources, get an impression of power relations and conflicting interests. These can be decisive for the success of an innovation or for applying transformation strategies. Equally, actors from the life-world can be motivated to reflect upon their own positions while being involved in the mapping process. They are likely to widen their perspectives by getting to know the patterns of interpretation of actors from other contexts.

Constellation analysis facilitates a systematic approach to problems in sustainability research within three steps: firstly, identifying the main elements and the interrelations between them; secondly, describing the structure and characteristics of the constellation; and thirdly, exploring the dynamics of the constellation. Depending on the question of interest, it can be helpful for the analysis to compare constellations from different actors or from different phases.

A common understanding of the problem or the achievement of making different perspectives transparent can facilitate to bring results to fruition (transformative knowledge). The constellation analysis can help to simulate the change of certain elements (e.g. creation of a certain law or technological innovation) and the differences in the relations between certain actors. Scenarios of applying different policy measures and their effects on the whole constellation can be set up and compared. The actors involved receive support in decision making by visualizing certain consequences considering all unintended side effects. Problem analysis can also facilitate to identify missing elements or relationships.

Regarding the four principles that guide transdisciplinary projects, constellation analysis contributes to integration of multiple perspectives throughout the whole process. By visualizing complex interrelations and using a common language which can be understood by all disciplines and life-world actors, it also contributes towards contextualization. Especially in the first phase, it helps to specify the need for knowledge by identifying which questions the actors involved want to focus on. By mapping the perspectives of different actors or by setting up constellations in different stages of the research process, the method also contributes towards recursiveness.

Constellation analysis is not restricted to any particular scientific theory or discipline, but is applied primarily for linking different disciplines or perspectives. The basic idea is to bring together various approaches, data sources, and forms of knowledge to create a picture of the constellation at large that can be shared by all disciplines and actors involved. By including natural and technical elements as well as social actors and systems of signs, it draws the attention to the variety of factors which are influencing certain constellations. This "eye-opening" effect can help to search for appropriate multidimensional theoretical approaches instead of concentrating on one dimension only (e.g. the governance perspective only). Depending on the topic which is dealt with, an integrative theoretical approach containing for example elements from innovation research, structuration theory as well as multi governance research is needed to deal with complex life-world problems.

Constellation analysis is a helpful instrument for organizing inter- and transdisciplinary processes in sustainability and innovation research which have the same character in developing, emerging and industrial countries. The method could be especially fruitful in questions of technology or policy transfer between highly industrial and developing or emerging countries. By comparing the elements which build up the specific constellations in the two different settings, the challenges of a simple transfer could be made visible and it would be possible to develop an integrative, multilevel transfer strategy.

Notes

1 The constellation analysis has been developed by scientists of the Center of Technology and Society, Technische Universität Berlin and the Nexus Institute, Berlin (Schön *et al*., 2007). It has been applied in several projects of sustainability and innovation research.

2 The research project 'Innovation Biography of Wind Energy' was funded by the Volkswagen Foundation from 2004 till 2007 (www.ztg.tu-berlin.de).

[3] The research project 'Blocked Transition? Spaces of Thinking and Action for Sustainable Development' was funded by the German Ministry of Education and Research (BMBF) from 2003-2006 (www.blockierterwandel.de)

References

Becker, E. and Jahn, T. (eds.) (2006), *Soziale Ökologie: Grundzüge einer Wissenschaft von den gesellschaftlichen Naturverhältnissen*, Frankfurt, Germany and New York, USA: Campus.

Bechmann, G. (2000), 'Das Konzept der "Nachhaltigen Entwicklung" als problemorientierte Forschung. Zum Verhältnis von Normativität und Kognition in der Umweltforschung', in Brand, K.-W. (ed.), *Nachhaltige Entwicklung und Transdisziplinarität. Besonderheiten, Probleme und Erfordernisse der Nachhaltigkeitsforschung*, Berlin, Germany: Analytica: 31-46.

Bergmann, M., Brohmann, B., Hoffmann, E., Loibl, M. C., Rehaag, R., Schramm, E., and Voß J.-P. (2005), *Qualitätskriterien transdisziplinärer Forschung. Ein Leitfaden für die formative Evaluation von Forschungsprojekten*, Frankfurt a. M., Germany: ISOE.

Boeckmann, T., Nölting, B., and Schäfer, M., (2007), 'Forschung mit und für die Praxis – Reflektion der transdisziplinären Arbeitsweise im Projekt', in Schäfer, M. (ed.), *Zukunftsfähiger Wohlstand - Der Beitrag der ökologischen Land- und Ernährungswirtschaft zu Lebensqualität und nachhaltiger Entwicklung*, Marburg, Germany: Metropolis.

Böhm, B. (2006), 'Vertrauensvolle Verständigung – Basis interdisziplinärer Projektarbeit', in Blickwechsel - Schriftenreihe des Zentrum Technik und Gesellschaft der TU Berlin, 4.

Brand, K.-W. (2000), 'Nachhaltigkeitsforschung. Besonderheiten, Probleme und Erfordernisse eines neuen Forschungstyps', in Brand, K.-W. (ed.), *Nachhaltige Entwicklung und Transdisziplinarität: Besonderheiten, Probleme und Erfordernisse der Nachhaltigkeitsforschung*, Berlin, Germany: Analytica: 9-28.

Bromme, R. (1999), 'Die eigene und die fremde Perspektive: Zur Psychologie kongnitiver Interdisziplinarität', in Umstätter, W. and Wessel, K.-F. (eds.), *Interdisziplinarität – Herausforderung an die Wissenschaftlerinnen und Wissenschaftler*, Bielefeld, Germany: Kleine: 37-61.

Bruns, E., Koeppel, J., Ohlhorst, D. and Schön, S. (2008), *Die Innovationsbiographie der Windenergie: Absichten und Wirkungen von Steuerungsimpulsen*, Hamburg, Germany: LIT Verlag.

CASS and ProClim (eds.) (1997), *Forschung zu Nachhaltigkeit und Globalem Wandel: Wissenschaftspolitische Visionen der Schweizer Forschenden*, Bern, Switzerland.

Forschungsverbund 'Blockierter Wandel?' (eds.) (2007), *Blockierter Wandel? Denk- und Handlungsräume für eine nachhaltige Regionalentwicklung*, München, Germany: oekom Verlag.

Funtowicz, S. and O'Connor, M. (eds.) (1999), 'Science for sustainable development', in Special issue of *International Journal of Sustainable Development*, 2 (3): 397-410.

Gibbons, M. and Novotny, H. (2000), 'The Potential of Transdisciplinarity,' in Klein, H.T., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, R.W. and Welti, M. (eds.), *Transdisciplinarity: Joint Problem Solving among Science, Technology and Society. A effective way for managing complexity*, Basel, Switzerland, Boston, USA, Berlin, Germany: Birkhäuser: 67-80.

Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P. and Trow, M. (1994), *The New Production of Knowledge: The dynamics of science and research in contemporary societies*, London: Sage.

Giri, A.K. (2002), 'The calling of a creative transdisciplinarity,' in *Futures*, 34 (1): 103-115.

Hirsch-Hadorn, G., Maier, S. and Wölfing-Kast, S. (2002), *Transdisziplinäre Forschung in Aktion: Optionen und Restriktionen nachhaltiger Ernährung*. Zürich, Switzerland: vdf Hochschulverlag.

Jahn, T. (2003), 'Sozial-ökologische Forschung. Ein neuer Forschungstyp in der Nachhaltigkeitsforschung', in Linne, G. and Schwarz, M. (eds.), *Handbuch Nachhaltige Entwicklung: Wie ist nachhaltiges Wirtschaften machbar?* Opladen, Germany: Leske-Budrich: 545-555.

Klein, J.T. (1996), *Crossing Boundaries: Knowledge, Disciplinarities and Interdisciplinarities,* Charlottesvielle: University Press of Virginia.

Kruse, S. (2010), *Vorsorgendes Hochwassermanagement im Wandel: Ein sozial-ökologisches Raumkonzept für den Umgang mit Hochwasser*. Wiesbaden: VS Verlag für Sozialwissenschaften.

Kruse, S. (2008), 'Structuring Multiple Perspectives in Environmental Decision-Making: Flood Protection in the Middle Elbe River', in Edmundson, R. and Rau, H. (eds.), *Environmental Argument and Cultural Differences: Locations, Fractures and Deliberations*, Oxford, Great Britain: Peter Lang: 37-64.

Lange, H. (2003), 'Interdisziplinarität und Transdisziplinarität. Eine "Wissenschaft neuen Typs" oder "vergebliche Liebesmüh"?', in Linne, G. and Schwarz, M. (eds.), *Handbuch Nachhaltige Entwicklung*, Opladen, Germany: Leske und Budrich: 563-574.

Latour, B. (1987), *Science in Action: How to Follow Scientists and Engineers through Society*, Milton Keynes: Open University Press.

Limoges, C. (1993), 'Expert knowledge and decision-making in controversy contexts,' in *Public Understanding of Science*, 2 (4): 417-426.

Loibl, M.C. (2005), *Spannung in Forschungsteams: Hintergründe und Methoden zum konstruktiven Abbau von Konflikten in inter- und transdisziplinären Projekten*, Heidelberg, Germany: Carl-Auer Verlag.

Loibl, M.C. (2006), 'Integrating perspectives in the practice of transdisciplinary research,' in Voß, J.-P., Bauknecht, D. and Kemp, R. (eds.), *Reflexive Governance for Sustainable Developmen*t, Cheltenham, Great Britain: Edward Elgar: 294-309.

Lowe, P. and Phillipson, J. (2009), 'Barriers to research collaboration across disciplines: scientific paradigms and institutional practices' , in *Environment and Planning*, 41 (5): 1171-1184.

MacMynowski, D.P. (2007), 'Pausing at the brink of interdisciplinarity: Power and knowledge at the meeting of social and biophysical science,' in *Ecology and Society*, 12 (1): 20.

Maier-Begré, S. and Hirsch-Hadorn, G. (2002), 'Options & Restrictions: A Heuristic Tool in Transdisciplinary Research for an Effective Implementation of Sustainable Practices,' in Biermann, F., Campe, S. and Jacob, K. (eds.), *Proceedings of the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change: "Knowledge for the Sustainable Transition - The Challenge for Social Science"*, Global Governance Project, Amsterdam, Netherlands, Berlin, Potsdam and Oldenburg, Germany: 322-336.

Mittelstraß, J. (2005), 'Methodische Transdisziplinarität,' in *Technikfolgenabschätzung – Theorie und Praxis*, 2 (14), Available at: www.itas.fzk.de/tatup/052/inhalt.htm (accessed on: 10 February 2010).

Mogalle, M., (2001), *Management transdisziplinärer Forschungsprozesse*, Basel, Switzerland: Birkhäuser

Nölting, B., Voß, J.-P. and Hayn, D. (2004): 'Nachhaltigkeitsforschung - jenseits von Disziplinierung und "anything goes",' in *GAIA*, 13: 254-261.

Nowotny, H., Scott, P. and Gibbons, M. (2001), *Re-thinking Science. Knowledge and the Public in an Age of Uncertainty*, Cambridge: Polity Press.

Ohlhorst, D. (2009), *Windenergie in Deutschland. Konstellationen, Dynamiken und Regulierungspotenziale im Innovationsprozess*, Wiesbaden, Germany: VS-Verlag.

Pfriem, R., Raabe, T. and Spiller, A. (2006), 'Von den Vorteilen und Risiken transdisziplinärer Forschung', in Pfriem, R., Raabe, T. and Spiller, A. (eds.), *OSSENA - Das Unternehmen nachhaltige Ernährungskultur*, Marburg, Germany: Metropolis-Verlag: 473-484.

Pohl, C. and Hirsch-Hadorn, G. (2006), *Gestaltungsprinzipien für die transdisziplinäre Forschung: Ein Beitrag des td-net*, München, Germany: oekom-Verlag.

Pohl, C. and Hirsch-Hadorn, G. (2007), *Principles for Designing Transdisciplinary Research: Proposed by the Swiss Academies of Arts and Sciences*, München, Germany: oekom Verlag.

Pohl, C. and Hirsch-Hadorn, G. (2008), 'Methodological challenges of transdisciplinary research,' in *Natures Sciences Sociétés*, 16 (1): 111-121.

Schäfer, M. (2007), 'Wissenschaft, die sich den Herausforderungen der Zukunft stellt: Charakteristika der Nachhaltigkeitsforschung', in Amelung, N., Mayer-Scholl, B., Schäfer, M. and Weber, J. (eds.), *Einstieg in nachhaltige Entwicklung*, Frankfurt a. M., Germany: Peter Lang: 21-37.

Schäfer, M. and Boeckmann, T. (2004), 'Integration of popular knowledge in sustainability research,' *Paper for the International Sociology Conference "Environment, Knowledge and Democracy"*, 6th-7th of July, Marseille, France.

Schön, S., Kruse, S., Meister, M., Nöltin,g B. and Ohlhorst D. (2007), *Handbuch Konstellationsanalyse: Ein interdisziplinäres Brückenkonzept für die Nachhaltigkeits-, Technik- und Innovationsforschung*, München, Germany: oekom Verlag.

Schmidt, J.C. and Grunwald, A. (2005), 'Method(olog)ische Fragen der Inter- und Transdisziplinarität. Wege zu einer praxisstützenden Interdisziplinaritätsforschung', in *Technikfolgenabschätzung – Theorie und Praxis*, 2 (14), Available at: www.itas.fzk.de/tatup/052/inhalt.htm (accessed on: 10 February 2010).

Schophaus, M., Schön, S. and Dienel, H.-L. (eds.) (2004), *Transdisziplinäres Kooperationsmanagement: Neue Wege in der Zusammenarbeit zwischen Wissenschaft und Gesellschaft*. München, Germany: oekom Verlag.

Siebenhüner, B. (2004), 'Social Learning and Sustainability Science: Which Role Can Stakeholder and Participation Play?,' in Biermann, F., Campe, S. and Jacob, K. (eds.), *Proceedings of the 2002 Berlin Conference on the Human Dimensions of Global Environmental Change: "Knowledge for the Sustainable Transition - The Challenge for Social Science"*, Global Governance Project Amsterdam, Netherlands, Berlin, Postdam and Oldenburg, Germany: 76-86.

Strübing, J., Schulz-Schaeffer, I., Meister, M. and Gläser, J. (eds.) (2004), *Kooperation im Niemandsland: Neue Perspektiven auf Zusammenarbeit in Wissenschaft und Technik*. Opladen, Germany: Leske-Budrich.

von Blanckenburg, C., Böhm, B., Dienel, H.-L. and Legewie, H. (2005), 'Leitfaden für interdisziplinäre Forschergruppen: Projekte initiieren - Zusammenarbeit gestalten', *Blickwechsel - Schriftenreihe des Zentrum Technik und Gesellschaft der TU Berlin*, 3, Stuttgart, Germany: Steiner.