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From science to policy through transdisciplinary research

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ABSTRACT

Is transdisciplinary research a useful means of bridging science and policy? And does transdisciplinarity go beyond informing public agencies, the private sector, or civil society of the results of research? The interacting policy cultures serve as a framework for studying transdisciplinary projects funded by two environmental research programs, the Swiss Priority Program Environment (SPPE) and the Swedish Foundation for Strategic Environmental Research (MISTRA). Two types of projects are distinguished. Researchers in projects of the first type reorganize knowledge according to the (perceived) interest of the audience. Transdisciplinary research of this type requires a clearly defined audience culture. Researchers in projects of the second type initiate a co-production of knowledge during which the different policy cultures interact. Transdisciplinary research of type two is appropriate for policies that have to be developed using a collective process involving multiple policy cultures.

1. Introduction

During the last decades scholars in the USA and Europe explored two different ways of bridging science and policy in environmental matters. In this case, science stands for knowledge about causes, effects and mitigation of environmental problems. The natural sciences, the social sciences, medical and engineering sciences, and the humanities provide such knowledge. Policy is understood in an abstract sense as a principle or guideline for action in a specific everyday-world context (for a series of definitions see Clark, 2002, p. 6). Policies are implemented in different sectors of the everyday-world, such as public agencies, the civil society or the private sector. The US American's and the European's differ in whom they consider to be responsible for bridging science and policy. In the USA Jasanoff (1992) concludes in her analysis of risk management at EPA that after a period of intermingling, the boundaries between science and policy were re-established. Jasanoff (1997, p. 582) judges such boundary drawing as indispensable in environmental decision making to prevent total paralysis of the decision making process, specifically when dealing with uncertainty. Guston (1999, 2001) finds that particular boundary organizations permit the flow of information between science and other sectors of society, and at the same time stabilize the boundaries. The US American Office of Technology Transfer is such a boundary organization between science and the private sector. The International Research Institute for Climate Prediction (IRI), standing between "climate modeling and forecasting on one end, and agricultural, health, and other social and political decision making on the other" (Agrawala et al., 2001, p. 471) is another. NGOs, even though not explicitly termed as such, can be boundary organizations that "bridge the lay–expert, activist–professional and local–global divide" (Jasanoff, 1997, p. 581). The term co-production – a core concept of transdisciplinary research – in this context stands for "simultaneous production of knowledge and social order" Guston (2001, p. 401).

In contrast, since the early 1990s a number of European environmental research programs, have followed the idea that

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science is responsible for the bridge between itself and policy. ''Transdisciplinarity'' or ''transdisciplinary research'' are used as terms for this approach in German speaking countries (Germany, Austria and Switzerland) and in Nordic Countries like Sweden and Finland. Transdisciplinarity can be traced back to Jantsch (1972). Within his system theoretic thinking Jantsch proposed that multi-, pluri-, cross-, inter-, and transdisciplinarity refer to various levels of coordination within the science, education and innovation systems. Transdisciplinarity represents the overall coordination of science, education and innovation towards a specific societal purpose. The German philosopher Mittelstraß (1992) reintroduced the term, in the context of environmental research, at the time when the Swiss Priority Program Environment was initiated. In agreement with the statement that ''the world has problems, but universities have departments'' (Brewer, 1999, p. 328), Mittelstraß called for a collaboration of disciplines across disciplinary boundaries and relating to problems in the everyday-world (life-world). Some years later the discussion of knowledge production in the context of application (Gibbons et al., 1994; Nowotny et al., 2001), known as Mode 2, added participation as a further element to transdisciplinarity (Klein et al., 2001; Defila and Di Giulio, 2001). Co-production of knowledge in this context is a collaborative process of knowledge production that involves multiple disciplines and stakeholders of other sectors of society.

Several European environmental research programs require projects to follow a transdisciplinary research approach before they qualify for funding. The first was the Swiss Priority Program Environment (SPPE, 1992–2000). This was followed by the Swedish Foundation for Strategic Environmental Research (MISTRA, since 1994), the Austrian Landscape Research (KLF, since 1995), and the German Social Ecological Research (SÖF, since 1999). All these require a transdisciplinary approach for pragmatic reasons, as the research is aimed at helping solve society's environmental problems. For example in 1992, during the SPPE steering committee's first meeting, a member of the committee stated that as research had produced a fair amount of knowledge about environmental problems it was now time for research to focus on problem solving. This pragmatic approach to transdisciplinarity differs from the French approach, represented by Nicolescu (1996), which sees transdisciplinarity primarily as a science beyond and between all disciplines.

The pragmatic orientation delayed meta-studies on transdisciplinarity as a specific form of research. The methodological and theoretical aspects (Nölting et al., 2004; Hirsch Hadorn et al., 2006; Höchtl et al., 2006; Wiek, 2007; Truffer, 2007; Pohl and Hirsch Hadorn, 2007) and the practice of transdisciplinary research (Pohl, 2005; Loibl, 2006; Lieven and Maasen, 2007) have only recently been systematically studied. Such studies are crucial to the development of transdisciplinary research, as an alternative approach to bridge science and policy. In the following, four transdisciplinary research projects from the Swiss SPPE and the Swedish MISTRA will be analyzed. The leading questions are whether the researchers entered a co-production of knowledge and what kind of problems they met when stepping over the boundaries of science.

2. Analytical framework: interacting policy cultures

In transdisciplinary research and in boundary organizations researchers and stakeholders from diverse sectors of society meet and exchange information. Such exchange must take into account, that each of the sectors – science, the private sector, public agencies and civil society – organizes knowledge and action according to individual time scales, categories, priorities, etc. Each sector of society is a separate social world (Star and Griesemer, 1989, p. 388) or culture, characterized by specific norms, knowledges, practices and discourses (Jasanoff and Wynne, 1998, pp. 16–18; Miller, 2001, p. 485). Members of each culture may look at the same situation and come to opposite conclusions of what is, and what has to be done. Based on their cultural norms, knowledges, practices and discourses they focus on the various elements of the situation and interrelate and interpret them differently. Limoges (1993, p. 420) speaks of ''worlds of relevance'', instead of social worlds or cultures, to place emphasis on alternative cultural reference systems as a potential source of controversy.

In transdisciplinary research members of the different cultures interact to co-produce knowledge. Elzinga and Jamison (1995, pp. 575–577) and Elzinga (1996, pp. 226–229) distinguish four such interacting cultures for analyzing science policy agendas, and global climate change research: the bureaucratic, the academic, the economic and the civic policy culture. The policy cultures are ''competing for resources and influence, and seeking to steer science and technology in particular directions'' (Elzinga and Jamison, 1995, p. 575) and are each characterized by their policy; the bureaucratic culture is concerned with effective administration, coordination, and organization; the academic culture seeks to preserve autonomy, integrity, objectivity and control over funding and organization of science; the economic culture is interested in transforming scientific results into successful innovations to be diffused in the commercial marketplaces; and the civic policy culture is concerned with the consequences and implications of developments in science and technology.

Van Kerkhoff and Lebel (2006, p. 470) propose that the bridge between science and policy be conceptualized as an arena: ''This allows us to point to specific instances where research based knowledge and action are interacting but without necessarily implying that those interactions are simple or straightforward''. Jasanoff and Wynne (1998, p. 17) depict knowledge production as a system of the four interacting policy cultures (Fig. 1). The term ''system'' means that the emphasis of an analysis shifts from the policy cultures to the way they interact (Jantsch, 1972, p. 103). The academic policy culture – keen to preserve its autonomy and integrity – mainly informs the other cultures. It serves the economic culture by technology transfer, it ''speaks truth to power'' (Price, 1965; Wildavsky, 1987) to the bureaucratic culture and it informs the civic culture about new scientific insights in order to enhance public understanding of science. From the perspective of the academic policy culture, the other cultures try to restrict its autonomy. The economic policy culture influences the academic by making research more market-driven and by insuring projects and programs are evaluated

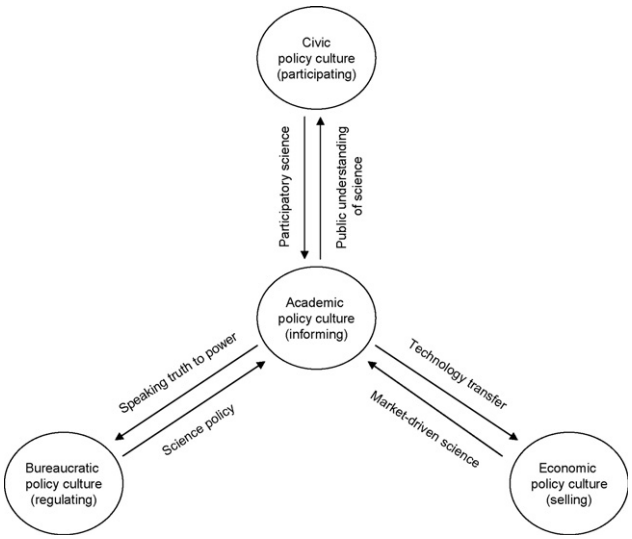

Fig. 1 – Knowledge production as a system of interacting policy cultures (based on Elzinga and Jamison, 1995; Jasanoff and Wynne, 1998, p. 17).

according to the economic profit they promise. The bureaucratic culture steers the academic culture by policy-driven research programs but also by setting limits to science, as in the case of genetic engineering. The civic culture influences the academic culture by ''enlarging civic participation or articulating underexposed points of view'' (Wachelder, 2003, p. 264).

The interactions depicted in Fig. 1 are ''ideal-typical'' simplifications in Weber's sense (1973). They stress particular characteristics of the policy cultures, and the way they relate to each other. This over-simplified form has no direct equivalent in reality. The simplification is motivated by the need to analyze knowledge production in transdisciplinary research. If transdisciplinary research is a process of co-production of knowledge, then research will go beyond the role of providing information and the academic policy culture must find ways to interact with the other cultures and their policies.

3. Materials and methods

Research projects from two environmental research programs – the Swiss Priority Program Environment (SPPE, http://www.sppe.ch) and the Swedish Foundation for Strategic Environmental Research (MISTRA, http://www.mistra-research.se) – provided the material for this analysis. In both programs the problem-driven collaboration of researchers from different disciplines and social stakeholders was considered crucial to the success of projects. The SPPE closed with an international conference on transdisciplinarity in 2000, signaling that a lasting outcome of this program should be ''different academic disciplines working jointly with practitioners to solve a real-world problem'' (Klein et al., 2001, p. 4). MISTRA was engaged in a conference on ''interdisciplinary and problem-oriented research and practice'' in 1998 (Brewer and Lövgren, 1999). In addition, MISTRA states on its homepage that '' [a] MISTRA programme is considered a success when scientifically advanced research has been put to practical use in companies, authorities or other organisations'' (MISTRA, 2007).

The SPPE and MISTRA were both created to establish problem-driven research in the field of environmental science. Research in both programs is structured for that purpose in the following way: sub-units – so-called modules – group 10–20 individual research projects around one particular issue, such as coastal management, sustainable nutrition, transboundary air pollution, biodiversity or waste. Four such modules will be analyzed. The analysis is based on interviews with researchers who were involved in the modules. In total, 27 interviews of about 1 h were held with researchers from 10 modules and with the management from both programs. To find the interview partners the head of each module was asked to name natural and social scientists who were particularly involved in, or responsible for, the transdisciplinary approach. For the fieldwork a partly standardized interview method was chosen: the problem-centered interview (Flick et al., 1991: p. 178ff.) in which the interviewer provides only marginal thematic orientations to stimulate the interviewee to formulate and conceptualize the issues of concern. The results thus show each researcher's perception of their role as transdisciplinary researchers. In order to maintain data confidentiality no detailed personal information will be given and no reference will be made to the projects' publications.

4. Results and interpretation

For the purposes of analysis the interview passages that dealt with interacting policy cultures were considered. According to the analytical framework this is the case when the researchers go beyond merely informing the other cultures and begin to take on further tasks. Two types of modules can be distinguished. Researchers in projects of the first type remain close to the academic culture's policy to inform, but add reorganizing knowledge as a further task. Researchers in projects of the second type become participant facilitators of a co-production of knowledge involving multiple policy cultures.

4.1. *Type one: reorganizing knowledge*

Several researchers agreed, in principal, that passing on information was the core task of the academic policy culture. In addition they were concerned with reorganizing knowledge from different disciplinary fields and presenting it to the audience. The audience and its interest is to some extent imagined, meaning that representatives of the audience were not involved in the planning of the modules and the results of the project do not respond to the explicitly formulated demands of the audience.

A first module of type one – ''community'' – analyzed strategies to induce sustainable development at the community level. Researchers trained in disciplines like economics, psychology, sociology or law studied the potential of regulatory and economic instruments, communicative and diffusive

instruments, collaborative agreements and changes in infrastructure as means to induce social change. It was the program's management that merged these projects into one module. Before, the researchers assumed that each project had to report its results individually. The fact that they became one module initiated an internal discussion process:

> Since we all deal with strategies and instruments, we have to develop a common understanding of what we mean: What is an instrument? What is a strategy? What are the different instruments and strategies? Which of those am I studying in my project? (Social scientist)

The discussions yielded a ''typology of tools'', which was, according to the module leader, the main result of the module's synthesis work. The typology presented the results of the disciplinary projects as alternative instruments, like a toolbox for community mayors. The closing workshop of the module took place in one of the communities that had been studied. The researchers performed a role-play on stage. On the left a community representative sat at his desk; on the right sat all the researchers. Their job was to convince the community representative that their approach to the problem was unquestionably the best solution: that the way forward was through economic incentives, decrees, structural changes or education by advertisement. After a period of trading the conclusion was that a combination of all these instruments would probably best fit the particular context of all the communities.

The academic and the bureaucratic policy cultures were involved in the ''community'' module. The academic policy culture informed the bureaucratic policy culture. Additionally, the academic policy culture reorganized the findings in a synthesis process, presenting them as tools that could be used by community representatives. From the user's perspective such a synthesis process may seem self-evident and not worth mentioning. Those who have been involved in a project with researchers from different disciplines (e.g. economics, psychology and sociology), will know the long and intensive discussions that are needed before everyone will accept their own disciplinary perspective as one amongst others and to relate the disciplinary results to a practical purpose (Giri, 2002; Loibl, 2005).

A second module of type one – ''soil'' – developed biological soil remediation technologies. At one site the capacity of plants to extract heavy metals from contaminated soils was studied. At another oil-polluted site, crude-oil-decomposing micro-organisms were applied. The natural scientific projects of the module explored new technologies. The social scientific projects considered the assessment of alternative technologies.

As the assessment group came from a multi-criteria decision making background, the members wanted to conduct a survey in which they would ask the residents for their preferences about alternative soil remediation technologies. Before the survey began a dossier (based on the research group's area of expertise) was distributed to the residents informing them, amongst other things, about the risks of contaminated soil and about uncertainties. The researchers thought of this as neutral information, but the dossier alarmed not only the residents, who suspected the community authorities of downplaying the real danger of the situation, but also the governmental agency responsible for contaminated soil and its remediation and for informing the public. As a consequence of this situation a further survey, intended to compare the residents' attitude towards the oil-eating micro-organisms and their attitude to genetically modified organisms, was prevented by the agency. A natural scientist who was involved understood the reason for the ban: such a survey would ''wake sleeping dogs'', by making people suspect the researchers of having already tested genetically modified organisms without telling them.[1]

The role of the academic policy culture in the ''soil'' module was primarily to inform. In addition, an assessment of alternative soil remediation technologies would be provided. Such an assessment – an evaluation of the social, ecological and economic pros and cons of technologies – contributes to a rational decision making process. The ''soil'' module did not yield such an assessment since government felt challenged by the researchers' initiative to inform the residents about soil pollution and since in this case there was no clearly identified addressee. The interaction of the academic and the bureaucratic policy cultures ended in a conflict about who had the authority to inform the residents. Such a conflict is what Gieryn calls boundary work (1983). Boundary work adjusts the boundary between the academic and the governmental policy culture, but it does not question the boundary as such. In the ''soil'' module transdisciplinary research aimed at going beyond informing by reorganizing knowledge. It was intended that the knowledge be used in a process of rational decision-making. In the end, however, boundary work was the only way the academic policy culture interacted with the other policy culture.

4.2. *Type two: co-producing knowledge*

Whereas type one projects remain close to the academic culture's policy to inform, type two projects facilitate a co-production of knowledge and at the same time participate in this process. Co-production means that the interaction between several policy cultures becomes a core element of the research process.

The ''waste'' project is a first example of type two. In this project, technologies for treating solid waste were developed in close collaboration with industry. Most of the projects were located at the research and development divisions of private companies. A natural scientist from a federal research institute was responsible for coordinating the module. He reported that the nature of the collaboration changed over time:

> First there were just self-interests. That was not easy to handle in the beginning. During the first meeting [...] we were all sitting around a table ... nobody dared to say anything, because everybody was afraid that the others would immediately spy on him or her. [...] To the end of the

[1] In Europe the public is generally sceptical of genetically modified organisms, especially if they are released into the environment.

> project people were rather open to each other in project matters, like colleagues. [...] And that was a piece of what I perceived as my work. That's a piece of – not sociology as a science – but practically used sociology, isn't it? (Natural scientist)

In order to make the competitors work in partnership, at least to some extent, collaboration and ownership had to be framed. Written rules, signed by the researchers, were established that prescribed when, and by whom, information could be classified as confidential; what that meant for the further handling of the information; and an agreed procedure for dealing with possible conflict. Besides this, the position of project observer was established. The observers came from industry, government or environmental organizations working in the field of waste. Again, they had to agree on certain rules and duties concerning information before being given the status of observer. The status of observer was established to anchor the project in the wider waste community.

> The point is, that the circle of those interested in waste management in our country is big, much bigger than the group of people involved in our module [...]. And that means: not only have sociologists, political scientists or economists to be involved, but also a much closer circle. [...] We have to include the people that do not form part of the module, but are closer to waste management than the outside world. (Natural scientist)

Rules of collaboration and the status of an observer were introduced to encourage researchers and observers to talk to each other, and to enhance mutual understanding, in order to make the module a collective endeavour. The collective nature of the collaboration was also addressed, when the coordinator reported on how he tried to orient the module's research towards sustainable development.

> I said to them: look, it is very clear to me that you are all potential competitors, must be like this, it's how our system works. But on the other hand it might be useful to have a club somewhere, that is not looking at the short-term profit only, but is also asking: ''Where in fact is north?'' [...] And I tried to tell them: ''North is that the waste of today is the raw material of tomorrow''. (Natural scientist)

In the ''waste'' module the researcher initiated an exchange of ideas within the module and with stakeholders of the waste management community. Furthermore, a normative orientation to the module's work was proposed. The desired direction (''north'') would be to think long-term, not short. In doing so the researchers leave the academic culture's policy to inform and become participant facilitators of a collective process of co-production of knowledge. Not only the academic, but also the other policy cultures are framing the co-production. The economic policy culture is articulated by perceiving knowledge as something that can be owned, transformed to marketable products and sold. This is taken up in the project by way of the rules of ownership and by classifying knowledge. Moreover, the economic, the civic and the bureaucratic policy cultures are represented by the observers. The transdisciplinary researcher in such a co-production is less concerned with establishing and maintaining boundaries and more with defining procedural rules, enhancing mutual understanding, and proposing normative orientations to make the co-production a collective process of policy cultures.

The ''coast'' module provides a second example of type two. The module addressed the conflicting interests involved in using coastal zones:

> How in the coastal zone do we resolve the conflicts between different types of users of the environment? Some people want to use the coastal zone just to get rid of wastewater, others want to use it for bathing, others for fishing, and so on. And there will be conflicts. And how can these be solved? (Natural scientist)

Some of the stakeholders involved in that conflict – several fishing research institutes, in part affiliated to the fishery department – had their own projects in the module and had been in close contact with fishermen for many years. The researchers studying the conflict situation used these institutes as contacts to get in touch with the fishermen and to inform them about the study on conflict. The researchers judged the present handling of conflict as an indirect management that focused on technical questions of fishing rather than on the real issues. The researchers thus published conflict studies – one on farming mussels, and one on fishing – called outreach reports, written in a popularized language. The stakeholders eagerly requested these studies. It was intended that the outreach reports would make the conflict into an openly debated public issue. Asked about the role of research in the ongoing project and specifically in conflict resolution, one researcher stated:

> A problem may be that we are asked to produce what I would call technical conflict solutions, and to assess the pros and cons. What are the pros and cons if we decide in the conflict between the seals and fishing: ''Hunting allowed for a defined period of time''. You cannot say with all your scientific identity and persuasiveness: ''Yes, that is the present state of knowledge.'' It is much more about reviving the stakeholders' attitude to look at things from different viewpoints. And that science has its limits, too. [...] And that – starting from the utopian model of transdisciplinarity – we have to develop solutions collectively and in conscious recognition that there is no monopoly for scientific knowledge. (Social scientist)

The researchers in the ''coast'' module induced a public debate on the conflict and its management. They informed the involved policy cultures by outreach reports consistent with the academic culture's policy to inform. Information, however, was primarily a means of initiating a public debate. The researchers saw their role as facilitators of a debate based, amongst other things, on scientific information; but without the academic policy culture being given the monopoly for informing the other cultures. The civic, the bureaucratic and the economic policy cultures were involved as stakeholders in

the public debate. Again the boundaries and the way they could be upheld was of minor interest compared to question of how a collective search for conflict resolutions could be initiated.

5. Discussion

In what respect does transdisciplinary research differ from the concept of boundary organization? The results indicate that transdisciplinary projects are too heterogeneous to answer the question directly. Projects funded by transdisciplinary programs do not necessarily lead to a co-production of knowledge by multiple policy cultures. Some researchers perceive their role in initiating such co-production (type two), others in reorganizing knowledge within the academic policy culture (type one).

Transdisciplinary research of type one, such as in the ''soil'' and ''community'' modules, does not really differ from, for example, the International Research Institute for Climate Prediction's (IRI) work as a boundary organization (Agrawala et al., 2001). The boundaries between the academic policy culture and the audience culture are not blurred, but clearly visible and stabilized. This became particularly evident during the final presentation of the ''community'' module: the researchers who provided knowledge were sitting on the one side of the stage, while the community representatives as the audience were on the other side. Accordingly, researchers in type one modules have a clear idea of who is responsible for organizing knowledge within the boundary organization: the academic policy culture.

The aim of re-organizing – especially in the ''community'' module – is to present knowledge in a form that can be used by the audience. This is one step of what Sarewitz and Pielke (2007) call ''reconciling supply and demand for science'', even though they are discussing broad research fields, such as climate science. If the idea is downscaled to modules, then researchers in the ''community'' module identify the community representatives in a demand side assessment. Furthermore, the researchers perform a supply side assessment within the synthesis process, by realizing that the results of their studies can be presented to the demand side as if they were a ready-made toolbox. The assessment in the ''soil'' module is less clear in that respect, especially for the demand side: the addressee of the assessment is not further identified—and therefore is an imagined, powerful, rational decision maker. Despite the module's failure, such an assessment may generally be more successful, if it is part of an ongoing political process within which new regulations have to be found, like in the case of the integrated assessment and the international conventions and protocols on transboundary air pollution (Sundqvist et al., 2002; Farrell et al., 2001; Gough et al., 1998).

''Essentialist *do* boundary work; constructivist *watch* it get done . . .'', as Guston (1999, p. 87) quotes Gieryn (1995, p. 394). The academic and the bureaucratic policy cultures that struggle for the right to inform the public in the ''soil'' module are essentialists. But what are the researchers who facilitate co-production of knowledge in the ''waste'' and ''coast'' modules? What are researchers doing, when they initiate and are part of a collective and interactive process of the four policy cultures? Can such research be categorized as essentialist acting or constructivist observing?

Transdisciplinary researchers in type two modules are essentialist, since they initiate knowledge production of a specific kind and propose specific normative orientations for the module's overall development. At the same time they are constructivists, being aware of the multiple policy cultures and their divergent interests. They are, however, not interested in observing the policy culture's struggle for epistemic primacy, and instead take that fact as a starting point for the co-production of knowledge in a collective endeavor. It is this production of knowledge as a *collective endeavor* – and not as a domain of science – that characterizes type two transdisciplinary research and has not been adequately captured by the concept of boundary work and boundary organization.

Even though type two transdisciplinary research aims at a co-production of knowledge, the researchers have a clear idea about who should be responsible for organizing the co-production: the academic policy culture. The academic policy culture is thus one amongst others in the co-production, but remains the one that initiates and manages the process. The latter is included in discussions about concepts such as hybrid or boundary management. Miller (2001, p. 487) in his analysis of the Body for Scientific and Technological Advice of the UN Framework Convention of Climate Change concludes that such organizations have to be able to manage hybrids of policy cultures: ''[T]hat is, to put scientific and political elements together, take them apart, establish and maintain boundaries between different forms of life, and coordinate activities taking place in multiple domains'' (Miller, 2001, p. 487). The analysis of the four modules suggests that transdisciplinary research of type one and type two differ in the way they emphasize the tasks mentioned by Miller. Type one transdisciplinary research, which considers the academic policy culture to be responsible for reorganizing knowledge, is more engaged with establishing and maintaining boundaries, and with taking apart the political and scientific elements. Type two transdisciplinary research is more involved in bringing the policy cultures together and in coordinating their activities. Thus, Sundqvist et al. (2002, p. 153) must be referring to transdisciplinary research of type two, in their analysis on the science policy interaction in long-range transboundary air pollution. They find that: ''Taken together, there is no essential definition to be found in the actors' demarcations between science and policy, and there is no need for such demarcations in order to establish successful environmental regimes. On the contrary, what is needed are connections between actors with different viewpoints.''

Cash et al. (2003, pp. 8088–8089) – besides communication and translation – name mediation as a characterizing function of boundary management: ''Mediation worked in our cases by enhancing the legitimacy of the process through increasing transparency, bringing all perspectives to the table, providing rules of conduct, and establishing criteria for decision making''. This is what the ''waste'' module researchers did by proposing rules on ownership of knowledge and by introducing the position of an observer. Besides bringing the policy cultures to the table, the researchers also initiated a public debate about conflict management and a discussion on the module's overall orientation towards sustainable development. Quinlan and

Scogings (2004, p. 541) state that development researchers are not only researchers and facilitators, but also advocates and activists. That is, they switch between being essentialist actors and constructivist observers.

6. Conclusion

Is transdisciplinary research a suitable way to bridge science and policy? And is it different from what is done and discussed in the concept of boundary organizations? Based on an analysis of selected research modules of SPPE and MISTRA, and on the analytical framework of the four interacting policy cultures, the answer has to depend on the type of transdisciplinary research:

- Type one transdisciplinary research reorganizes knowledge that is produced with regard to the (perceived) audience and its demands. This type of transdisciplinary research does not differ significantly from research carried out in institutes described as boundary organizations. The researchers are concerned with establishing and maintaining boundaries between the academic and other policy cultures, and consider the academic policy culture to be responsible for reorganizing knowledge. Whether the reorganized knowledge suits the interest of the audience policy culture will depend on how clearly the audience policy culture and its interest are analyzed and defined.
- Type two transdisciplinary research participates in and facilitates a co-production of knowledge by the four policy cultures. The boundaries between the policy cultures are of minor interest, and the researchers' emphasis is on initiating and participating in the co-production of knowledge as a collective endeavor. The researchers consider the academic policy culture to be responsible for making the co-production of the four policy cultures (the academic being one of them) happen. Transdisciplinary research of type two is the appropriate way to bridge science and policy if, several policy cultures, besides the academic, are concerned and a co-production is needed. The researchers involved in the modules considered the development of sustainable waste technologies and the management of the coast as two such issues, where policies must be developed in a collective process of multiple policy cultures.

Even though re-organizing knowledge and facilitating a co-production of knowledge are two suitable ways for bridging science and policy, this does not imply that all scientists have to become transdisciplinary researchers. A core challenge for the future will be to develop a procedure for distinguishing issues that need to be handled by a disciplinary, a transdisciplinary (of type one or type two), or a different form of research.

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