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INTRODUCTION

Transdisciplinary Environmental Science: Problem-oriented Projects and Strategic Research Programs

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New modes of knowledge production and the Helmholtz Association

In the European context, transdisciplinarity refers to research strategies that not only cross disciplinary boundaries but also enable problems to be framed and solved together with stakeholders from outside the world of academic research. Knowledge produced jointly by scientists and non-scientists is geared especially toward enhancing the problem-solving capacity of the applied sciences and engineering by developing forms of expertise that are both scientifically sound and societally acceptable (Gibbons *et al*. 1994, Nowotny *et al*. 2001, Klein *et al*. 2001). However, perhaps the most prominent arena where such transdisciplinary processes have been implemented is in research on the environment and sustainability (Groß *et al*. 2003, Lang *et al*. 2012, Scholz *et al*. 2006). With surprising unanimity, the definitions and analysis of such transdisciplinary processes accord with similar definitions contained in the mission statement of the Helmholtz Association, the largest non-university research association in Germany. The opening sentence of this mission statement is: 'We contribute to solving grand challenges which face society, science and industry by performing top-rate research in strategic programmes in the fields of Aeronautics, Space and Transport, Earth and Environment, Energy, Health, Key Technologies as well as Structure of Matters'.[1] This is very much in line with the aims of transdisciplinary research and differs markedly from the guiding principles of other German research organizations such as those of the Max Planck Society, which focuses on basic research.[2]

Despite its explicit orientation towards problem-solving research, and unlike Mode 2 or post-academic knowledge production (see below) which seeks to further cooperation between the natural and social sciences, the Helmholtz Association's disciplinary makeup is more than ninety five per cent natural sciences and engineering research. To this date collaboration

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between the natural and social sciences is relatively scarce. In order to investigate this apparent mismatch between stated aims and disciplinary structure, this special issue looks closely at the nature of cooperation in some of the natural and social scientific research projects currently being undertaken at the Helmholtz Centre of Environmental Research — UFZ in Leipzig. UFZ is one of the few Helmholtz Centres with a high percentage of social scientists and a strong commitment to cooperation between the natural and social sciences. As such it can be seen as a touchstone of the possibility of conducting successful transdisciplinary research within a program-oriented research organization. This in turn can contribute towards identifying future opportunities and obstacles when it comes to organizing transdisciplinarity on a larger scale, that is, not merely within single projects. It seems reasonable to question whether the currently fashionable calls for closer interdisciplinary cooperation and synthesis among established disciplines are appropriate: after all, in many cases complex real world problems seem to require specialist input from many different disciplines working separately and building on their respective disciplinary strengths rather than engaging in exploratory collaborations that blur disciplinary boundaries (Behrens and Groß 2010, Frickel 2004, Groß 2004, Jacobs 2013). This attitude is encapsulated well in the title of Jerry Jacobs's well-known book *In Defense of Disciplines*. Surely there is good reason to ask whether — and in what instances — interdisciplinary collaboration is indeed superior to disciplinary approaches and research programs, especially when it comes to solving real world problems. To this end, we discuss first the recent observations put forward by scholars working in science studies and related fields regarding a change in the mode of science in the twenty first century, comparing them with the forms of knowledge production observed within the Helmholtz Association's program-oriented research set-up. This provides a context in which to embed the case studies of transdisciplinary research projects discussed in this special issue.

Transdisciplinarity and the Mode 2 thesis

Science studies analyses over the last thirty years have heralded a general change in science in the form of a new mode of knowledge production that is set to influence our understanding of science itself in the future. A number of concepts have emerged that reflect a change in the relationship between science, contexts of application, and the public. Some of those who have identified a fundamental change in scientific knowledge and its mode of production also call for a transdisciplinary science or a Mode 2 in knowledge production (e.g. Gibbons *et al*. 1994, Nowotny *et al*. 2001). One frequently cited description states that a transdisciplinary context of application has 'distinct theoretical structures, research methods and modes of practice . . . which may not be locatable on the prevailing disciplinary map' (Gibbons *et al*. 1994: 168). Transdisciplinary research is defined by its reference to and analysis of *socially* relevant problems. In a transdisciplinary perspective stakeholders need to be integrated (ideally) into all steps of the research process, starting from a joint process of framing the problem, moving through a core project phase involving the co-production of knowledge, and leading to a stage at which researchers and stakeholders alike are able to integrate the results that have been jointly obtained into their own respective contexts of application (Pohl and Hirsch Hadorn 2007, Hirsch Hadorn *et al.* 2008, Jahn *et al.* 2012).

According to its name giver, in Mode 2 knowledge production ‘transdisciplinarity is achieved by focusing on research problems as they emerge in contexts of application and where the heterogeneity of knowledge producers introduces additional criteria of assessment apart from scientific quality’ (Nowotny *et al*. 2001, 223). Transdisciplinarity thus addresses social, technical, and policy related issues where the primary goal is problem solving. Other scholars have sought to frame the impacts of a new type of science in terms of a recontextualization of science within society (Rip 2011), the emergence of a ‘triple helix’ among universities, industry, and governments (Etzkowitz and Leyesdorff 2000), and generalized declarations of a new age of postacademic (Ziman 1996) or postnormal (Funtowicz and Ravetz 1993, Ravetz 2012) science. Prefiguring these debates, an interdisciplinary group of scholars at the Max Planck Institute in Starnberg, Germany suggested in the 1970s that the relationship between science and society during the twentieth century had reached a stage in which scientific research needed to be guided by social, cultural or political objectives. This was called the finalization thesis or the stage of ‘finalized science’ (Böhme *et al*. 1976). Here, as in more recent approaches, the production of scientific knowledge is undertaken not in order to discover basic natural laws but to find societally relevant solutions.

The debate around transdisciplinarity, however, is normally traced to a conference organized in 1969 by the UNESCO in Geneva. One key outcome was the conceptual paper presented by Erich Jantsch (1970). For Jantsch, the university system and science should be directed clearly towards a new purpose, namely, ‘increasing the capability of society for continuous self-renewal’ (Jantsch 1970: 403). To this end, he called for close collaboration and integration across the different academic disciplines. In continental Europe this debate was taken up intensively — albeit some thirty years later — in Germany and Switzerland, leading to a first international conference held in the year 2000 in Zürich (Häberli *et al*. 2000, Klein *et al*. 2001). Joint problem solving among science, technology and society was not only the title of this conference but even more so the credo of its organizers. This conference was followed up in a wide variety of ways, including the development of design principles (Pohl and Hirsch Hadorn 2007), a handbook of transdisciplinary research (Hirsch Hadorn *et al*. 2008), quality and evaluation criteria as well as methods for transdisciplinary research (Bergmann *et al*. 2012) and numerous empirical studies based on them.

Overall, the debates on Mode 2 transdisciplinary science presented by Nowotny *et al*. (2001) appear to be a useful yardstick for the significance attached to problem-solving science. This is not necessarily because the authors’ conceptualizations of Mode 2 are more convincing or their empirical validity more thorough than alternative diagnoses of changing science systems but simply because Mode 2 is the most famous description of a transformation in contemporary science (Hessels and van Lente 2008). Indeed, Mode 2 has fostered a debate that extends as far as popular science magazines and even to the daily newspapers and weekly broadsheets. However, what unites all the above-mentioned perspectives with the Mode 2 thesis is that they all refer to changes in the organizational setting of scientific work that are intended to assert the authority of scientific knowledge and, especially, to ensure the democratic embeddedness of such knowledge within society.

With science having undergone a long period of specialization and differentiation into various disciplines and specialist fields, some observers of contemporary science claim that, due partly to increasing pressure on scientists to engage in applied science, today's research processes are ushering scientists towards more transdisciplinary forms of networking and knowledge production (Gibbons *et al*. 1994, Klein *et al*. 2001). This means that transdisciplinarity is not happening by choice but by necessity. As a result, problems increasingly emerge not only in the scientific context itself but also in the context of application in which solutions for a specific problem are developed. This debate has been accompanied by recent research on the democratization of science (Bäckstrand 2003, Jasanoff 2012, Lövbrand *et al*. 2011, Stilgoe *et al*. 2014). Expanding on these worthwhile lines of inquiry, this special issue will look at research processes in the context of the Helmholtz Association's program and problem-oriented research culture as illustrative examples of successful as well as not so successful transdisciplinary collaboration.

At first sight, transdisciplinarity appears to be a promising concept for better understanding new forms of knowledge production involving different forms of collaboration. Scholars in Europe tend to use a rather vague definition of transdisciplinarity, one which in many respects overlaps with many definitions of interdisciplinarity. These two concepts often share the notion of collaboration across scientific disciplines, between different social actors and a focus on problem solving (Frodeman *et al*. 2010). Perhaps the most important aspect of transdisciplinary research is that it seeks to address real world problems that are of special interest to certain groups of stakeholders or political leaders, rather than issues whose origin and relevance lie in scientific debates alone. Likewise, the two approaches are thoroughly established in more applied fields of research including urban development (Ramadier 2004), landscape planning (Tress and Tress 2001, Stauffacher *et al.* 2008), community psychology (Stokols 2006), public health (Lawrence 2004), and risk research (Horlick-Jones and Sime 2004, Renn 2014). Indeed lately they have even found their way into more mainstream arenas, one example being the Future Earth program of the International Council of Science, which emphasizes the role of stakeholders in both co-designing research and co-producing knowledge together with scientists (Future Earth 2013).

Working on a specific problem at a specific site requires innovative forms of research practice: researchers venture outside the (safety of the) laboratory walls in order to develop a solution for a single specific problem located in the 'real world'. Taking a single case as a starting point is a way of revealing exactly which problem the researchers are facing, while the specific structure of the problem itself channels the dynamics of socio-technological innovation as well as the research process per se. In order to capture the specifics of a case and develop appropriate solutions, relevant framing conditions have to be acknowledged as they become apparent. This means, in contrast to laboratory experiments, that variables and influencing factors cannot be controlled or defined in advance; instead, they emerge during the research process, and researchers have to incorporate them into their activities (Groß and Krohn 2005, Karvonen and van Heur 2014, Kullman 2013).

Program orientation in the German Helmholtz Association

In view of the developments described above, this special issue seeks to offer a critical and constructive contribution to the many debates on transdisciplinary problem solving. In doing so it draws on the particular experience of researchers within the German Helmholtz Association (HA) and its numerous partners all over the world in order to critically assess and to advance conceptualizations of inter- and transdisciplinarity. This experience is especially useful given that the Helmholtz Association is not only Germany's largest scientific research organization (with Max Planck in second place) but, unlike basic research oriented institutions (most universities), its official mission is to solve the grand challenges of society, science, and industry by means of research conducted in so called problem-oriented strategic programs.

The German Helmholtz Association currently employs around 34,000 researchers working in eighteen research centres. The Association's annual budget amounts to more than €3.8 billion. Rather than investing its resources in individual institutions, Helmholtz has established general research programs that compete with each other for funding. Researchers at the centres have developed twenty eight distinct research programs whose strategic relevance are evaluated rigorously by internationally renowned experts once every five years.[3]

A key focus of this special issue of *Interdisciplinary Science Reviews* is on networks of cooperation between the natural and social sciences and their connection to public policy and decision making (Fischer *et al*. 2011, Hirsch and Luzadis 2013, Weiland *et al*. 2013). Thus this special issue contributes first hand empirical research to recent debates on post-normal science, Mode 2 science, industry-science relations, as well as in more general terms to debates about the changing role of science in the twenty first century.

The issues and themes discussed range from the *assessment* of major research programs dealing with contaminated site management, the *governance* of large transdisciplinary environmental research projects, challenges for classical nature conservation and biodiversity research, urban and regional perspectives on sustainability issues, alternative energy systems, collaborative processes in integrated water resources management research, as well as climate change.

The aim of this special issue is that it not only to generate new insights into problem-oriented strategic research processes (such as Helmholtz's) but also to use transdisciplinarity more generally as a workspace for picking through the nuts and bolts of empirical research. This includes access to inside knowledge (especially crucial when it comes to precarious information) about the processes of transdisciplinary problem solving — access that facilitates much more than merely detached social observation.

Although the Helmholtz Association's eighteen centres are located in Germany, its research programs are implemented all over the world. Hence, the authors of this special issue literally come from all five continents, thus considerably enhancing the potential of their contributions to disseminate transdisciplinary knowledge in environmental research much more broadly.

The articles contained in this special issue

Filip Alexandrescu and co-authors give an example of a European research project coordinated by Helmholtz that looks at possible solutions to what they call 'dissonances' in research on and the management of contaminated sites. In this project a consortium consisting of natural and social scientists has developed an EU-funded research program aimed at providing problem-oriented, customized procedures and technologies for revitalizing contaminated areas. The authors are able to show that even fuzzy notions of transdisciplinarity can provide a door opener to both scientists and practitioners to engage in new collaborative modes of work. In so doing they also express clearly the pros and cons of program-oriented research environments in relation to enhancing the ability of the project team to generate solutions through transdisciplinary cooperation. Following this, Christoph Görg and co-authors discuss the integration of local knowledge within biodiversity research and reflect on their experiences from large inter- and transdisciplinary projects. Biodiversity management is a crucial issue for our understanding of transdisciplinary cooperation because research into it involves not only scholars from the sciences, social sciences and humanities but also holders of knowledge previously rendered non-scientific (experience-based or indigenous) (Sillitoe 2007). Görg *et al*. discuss this research experience against the background of the program-oriented research done at the Helmholtz-Centre for Environmental Research — UFZ over the course of the last ten years.

In the next article Katja Sigel and co-authors focus on transdisciplinary knowledge transfer in the context of two case studies on integrated water resources management in Ukraine and Mongolia. Sigel *et al*. assess how far the prerequisites for knowledge transfer can feasibly be met in transdisciplinary projects on integrated water resources management (IWRM). Continuing along this line of inquiry, Kerstin Krellenberg and Katrin Barth offer some reflections on their research into climate change adaptation planning in the city of Santiago de Compostela in Chile. They present in detail how collaboration between scientists and stakeholders took place throughout the entire process. The authors argue that inter- and transdisciplinary approaches to adaptation strategies have the potential to unravel the complexity of climate change and the interwoven processes it entails.

Finally, Jennifer Hauck and co-authors make an impelling case for discussing so-called linear research processes with transdisciplinary elements, focusing again on European biodiversity research. Unlike the focus adopted in Görg *et al*., Hauck *et al*. consider a network of environmental research institutes, critically scrutinizing transdisciplinary research processes that are often presented in a romanticized and ideal typical manner. They identify several problems to do with synchronizing policy and project cycles and highlight the advantages and disadvantages of network structures intended to facilitate long-term research cooperation, a major component of problem orientation in the Mode 2 literature and of the Helmholtz Association's mission. The issue is rounded off by Sigrun Kabisch's personal reflections of her understanding of inter- and transdisciplinary urban research in an environmental research institution.

Notes

1 On the mission and organizational structure of the Helmholtz Association see http://www.helmholtz.de/en/about_us/mission/.

2 For an overview, see http://www.mpg.de/183251/portrait.

3 Further information on the evaluation and review procedure can be found at http://www.helmholtz.de/en/about_us/programme_oriented_funding/.

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