How to bridge between natural and social sciences? An analysis of three approaches to transdisciplinary from the Swiss and German field of environmental research

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Cette analyse portant sur trois programmes de recherche interdisciplinaire (un en Allemagne et deux en Suisse allemande) a l'immense mérite de nous tenir informés sur ce qui se passe dans la communauté germanophone concernée par les questions d'interdisciplinarité mais aussi de révéler des notions communes. Par exemple celle de « l'objet frontière » ; est-ce lui qui détermine une démarche allant au-delà de la simple juxtaposition de disciplines ? Ce n'est pas l'habit qui fait le moine et il ne suffit pas de se dire « inter » ou « transdisciplinaire » pour en avoir la méthodologie ou de répondre à une supposée « demande sociale » pour mettre en œuvre un échange de savoirs qui se révélera heuristique.

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Introduction

Since about 10 years transdisciplinarity has been a concept of increasing importance in Swiss, Austrian and also German environmental research. During this period transdisciplinarity has by and by superseded interdisciplinarity as the preferred label. Parallel to this, emphasis was placed ever more on the collaboration between science and 'the public' and less on the collaboration between scientific disciplines.

Abstract – How to bridge between natural and social sciences? An analysis of three approaches to transdisciplinary from the Swiss and German field of environmental research.
There is a strong tendency in Swiss environmental research to conceive of transdisciplinary as if it would mean nothing but science bridging to society by addressing societal concerns. In contrast, an analysis of the recent discussion on transdisciplinarity shows, that the term includes at least five constitutive features: transdisciplinary research accordingly is problem-oriented, beyond disciplinarity, practice-oriented, participatory and process-oriented. To elaborate one of those features – to go beyond disciplinarity – three recent transdisciplinarity research methods are studied: 'Earth System' Analysis, the History of Matter and Goods and Synoikos. The aim is to illuminate the way in which researchers from the natural and social sciences collaborate and to learn about the intertwining of different disciplinary epistemologies. The encountered forms of collaboration are characterised as master-servant, deadlock, give-and-take and new-commonality. These forms of collaboration are further distinguished by applying boundary concepts from the social studies of science.

transdisciplinarity / transdisciplinary research methods / features of transdisciplinarity / environmental research / boundary work / boundary objects / 'Earth System' Analysis / History of Matter and Goods / Synoikos / collaboration between natural sciences and social sciences / collaboration between disciplines

This development holds especially true for the Swiss Priority Program Environment (SPP-E), within which one main part of Swiss environmental research took place during the 90s. The SPP-E program leader characterises the research that is undertaken in this program as 'oriented' research. 'Oriented' research is 'ordered' by society (e.g. by the way of parliament), starts from real world problems and yields results that (ideally directly) help to solve these problems (Häberli and Grossenbacher-Mansuy, 1998). During the last years, the aim to undertake "problem solving science" became so dominant that, in the end, the discussion on the exchange of knowledge between disciplines vanished into thin air. Consequently, recent criteria developed by SPP-E to evaluate transdisciplinary research (Defila and Di Giulio, 1999) are not sensitive to the manner and intensity with which researchers from different discipline collaborate (Pohl, 1999).

The outlined situation in Swiss, Austrian and also German environmental research is the background against which this paper is to be read, which means that the hidden agenda is to focus on what went lost during the SPP-E. In section 2, I will therefore try to reopen the term transdisciplinarity by developing five features of transdisciplinary research. For that purpose, four authorships' definitions are analysed that are important for the debate in German-speaking environmental research. In section 3, three examples of recent transdisciplinary research approaches are studied, each of which approaches the collaboration of the social and natural sciences in its own way: The 'Earth System' Analysis (Schellnbucher, 1999), the History of Matter and Goods (Huppenbauer and Reller, 1996) and Synoikos (Bacini and Oswald, 1998). A summary of each method is given to recapitulate the environmental problem that is addressed and the way in which it is tackled. Thereafter, a critical description is offered on how each method goes (far) beyond disciplinarity. Finally, in section 4, boundary concepts from the social studies of science (Gieryn, 1983), (Gieryn, 1995), (Star and Griesemer, 1989), (Klein, 1996) are introduced, to further disentangle the ways in which disciplinary epistemologies are interwoven.

Five features of transdisciplinary research

I consider the articles of Mittelstraß (1992), Jaeger and Scheringer (1998), Häberli and Grossenbacher-Mansuy (1998) and Defila and Di Giulio (1999) as constitutive for the Swiss discussion on transdisciplinarity in environmental research (*box 1*). The last two articles were written by or elaborated in collaboration with the management of the SPP-E. Through its cutting-edge function the SPP-E also influenced the discussion in Austria and partly in Germany.

Taking a closer look at the definitions the authors give on transdisciplinarity (*box 1*), five features can be

Box 1.

1. "Transdisciplinarity indicates knowledge or research that leaves the specialised and disciplinary boundaries, and that defines and solves problems with regard to science-external developments in a way that is independent from disciplines."
Original in German: "Mit Transdisziplinarität ist Wissen oder Forschung gemeint, die sich aus ihren fachlichen beziehungsweise disziplinären Grenzen löst, die ihre Probleme mit Blick auf ausserwissenschaftliche Entwicklungen disziplinunabhängig definiert und disziplinunabhängig lös" (Mittelstraß, 1992, p. 250).

2. "So in transdisciplinary research an extra-scientific problem is taken as the starting point for the research process" and "Working at problems of science-external origin in a scientific way, according to our proposition, requires a transdisciplinary manner of working. By saying that we mean a process of formulating and solving problems, which frees itself from disciplinary cognitive interests and methodological constraints even more effectively than by interdisciplinary work."
Original in German: "Bei transdisziplinärer Forschung ist also ein ausserwissenschaftliches Problem Ausgangspunkt des Forschungsprozesses" und "Die wissenschaftliche Bearbeitung von Problemen mit ausserwissenschaftlicher Herkunft erfordert, so unsere These, transdisziplinäres Arbeiten. Damit ist ein Prozess der Problemformulierung und Problemlösung gemeint, der sich - noch stärker als bei interdisziplinärem Arbeiten - von disziplinären Erkenntnisinteressen und Methodenzwängen löst." (Jaeger and Scheringer, 1998, p. 14).

3. "SPP-E (Swiss Priority Program Environment) strongly indicate that 'Transdisciplinarity' has to fulfil at least the following four conditions... a) The problems that are studied originate in the real world (Lebenswelt). The question is formulated and structured jointly or in close contact with representatives from the practice and those concerned. b) Teams are formed from experts of those disciplines that are required in order to answer the questions posed (alliances of disciplines), but also from representatives from the practice and those concerned. c) The research itself is carried out through the collaboration of the researchers and in close contact with the practice. d) Results are disseminated in the public at large."
Original in German: "Die Erfahrungen des SPP Umwelt sprechen dafür, dass 'Transdisziplinarität' mindestens die folgenden vier Bedingungen erfüllen sollte... a) Die zu erforschenden Probleme stammen aus der Lebenswelt. Die Fragestellung werden gemeinsam oder in engem Kontakt mit Vertretern der Praxis und den Betroffenen formuliert und strukturiert. b) Es werden Teams von Fachleuten derjenigen Disziplinen gebildet, die es für die Beantwortung der gestellten Fragen braucht (Disziplinenverbünde), sowie aus den Vertretern der Praxis und der Betroffenen. c) Die eigentliche Forschungsarbeit wird im Zusammenwirken der Forschenden und in engem Kontakt mit der Praxis durchgeführt. d) Die Ergebnisse werden in die breite Öffentlichkeit hinausgetragen." (Häberli and Grossenbacher-Mansuy, 1998, p. 200).

4. "Interdisciplinarity is understood as an integration-oriented cooperation of persons from at least two disciplines with regard to common goals, in which disciplinary views are combined to an integrated (overall-)view. Only those disciplines are included that are able to make a contribution to the particular topic." And "Transdisciplinarity, in turn, is understood as an interdisciplinary cooperation, in which, in addition, the science-external practice (e.g. the users) are participating in research, too."
Original in German: "Interdisziplinarität wird hier verstanden als eine integrationsorientiertes Zusammenwirken von Personen aus mindestens zwei Disziplinen im Hinblick auf gemeinsame Ziele, in welchem die disziplinären Sichtweisen zu einer Gesamtsicht zusammengeführt werden. Einbezogen werden jeweils diejenigen Disziplinen, die zur Bearbeitung des Themas etwas beitragen können" (Defila & Di Giulio 1999, 6). "Transdisziplinarität wiederum wird hier verstanden als eine interdisziplinäre Kooperation, in der darüber hinaus auch die ausserwissenschaftliche Praxis (z.B. Anwenderinnen und Anwender) an den Forschungsarbeiten beteiligt werden" (ibid., p. 13).

found that together form the concept of transdisciplinarity. Transdisciplinary research accordingly has to be: a) problem-oriented, b) beyond disciplinarity, c) practice-oriented, d) participatory and e) process-oriented:

a) Research is called *problem-oriented* if it concerns environmental problems. Problems additionally are marked as 'lebensweltlich', real or extra-scientific (Jaeger and Scheringer, 1998). This is mainly to emphasise that the problems studied affect society as a whole and do not only concern science-internal quarrels alone.

b) To go beyond disciplinarity can be understood in two ways. Weakly conceived, it says that disciplinary knowledge has to be exchanged in order to obtain a view on things that is more complete and coherent than a mere accumulation of disciplinary points of view. This shall be labelled as going *beyond disciplinarity*. Strongly conceived, it says that the mere exchange of disciplinary knowledge has to be overcome, too. Knowledge from different disciplines accordingly has to permeate into each other. Gibbons et al. (1994, p. 29) call it "the interpenetration of disciplinary epistemologies". Results gained in this way cannot easily be dissociated into their disciplinary components. Subsequently I will call this going *far beyond disciplinarity*.

c) Research is practice-oriented if it is designed with reference to a specific context of application. Practice-oriented means that research is done for a specific user and that the research results consequently have to be transformed into a convenient, usable product. Users are commonly conceived as persons from industry, from NGOs, from government or lay-people. Products are e.g. handbooks, devices, courses, exhibitions or programs (Defila and Di Giulio, 1999).

d) *Participatory* can be understood in a weak and in a strong way, too. *Weakly* understood it signifies that besides researchers also other people are included in the research project, for example users during the definition of the problem. As a *strong* claim it stresses that the input of the non-scientist has to influence the research results thoroughly, i.e. that scientist and non-scientists 'really' learn from each other and that the epistemologies of scientists and non-scientist interpenetrate each other respectively. In the following, and especially in *table I*, I will use participatory as a strong claim.

e) Process-orientation emphasises a highly interactive and communicative way of doing research. The place of knowledge production is no more the lonesome study alone, but also the collective process of permanent fitting and matching of the different views of the participants, be it users or other researchers. Process-orientation accordingly requires a very interactive approach to research.

Table I summarises the discussion on transdisciplinarity by illuminating the different positions. The columns indicate which of the features the authors mean when they refer to transdisciplinarity. The features that they address are shaded in grey or dark grey, the ones that are neglected remain in white. A grey cell indicates that the feature is addressed, whereas dark grey stands for features that are highly emphasised.

The first outcome of *table I* is that every authorship addresses only some of the features, whereas the question which ones these are depends on the authorship. The second outcome is that the features are alternatively assessed, i.e. that every authorship ascribes different relative weight to the selected features. All five features together – independent of their relative weight – frame the general and quite fuzzy concept of transdisciplinarity.

Table I specifies and clarifies the problems faced by transdisciplinary research methods in a first step. The table also shows what was mentioned above: For the time being the discussion on transdisciplinarity in the Swiss, Austrian and German environmental research does not place so much emphasis on the feature of 'going far beyond disciplinarity'

(Far) beyond disciplinarity – three recent transdisciplinary research approaches

The following three methods were chosen, because (at a first glance) they propose promising ways to combine knowledge from the natural sciences on the one hand and the social sciences on the other hand. In addition, in all three methods transdisciplinarity is mainly understood as the combination of knowledge from different

Table I. How do different authors understand transdisciplinarity?

	Mittelstraß (1992)	*Jaeger and Scheringer (1998)*	*Häberli and Grossenbacher-Mansuy (1998)*	*Defila and Di Giulio (1999)*
Problem-oriented				
Far beyond disciplinarity				
Practice-oriented				
Participatory				
Process-oriented				

Feature is not addressed (white), feature is addressed (grey), feature is emphasised (dark grey).

disciplines, whereas the other features of *table I* are not (or not yet) addressed. Probably the most significant difference between the three is the effort that has gone into them in terms of funding and researchers. To compare them as if they were equal implies the (certainly questionable) assumption that the ability to find new ways to combine disciplinary epistemologies does not depend on the invested money and time and the number of involved researchers.

Earth System' Analysis: Search for archetypal Syndromes, model and manage them

The 'Earth system' analysis approach was and is mainly developed at the Potsdam Institute for Climate Impact Research (PIK) in Germany[1]. The PIK is a research institute that engages around 150 researchers from various disciplines, the natural as well as social sciences. Founders of the institute are the federal government of Germany and the federal state of Brandenburg. The head of the PIK is Prof. Dr. Hans-Joachim Schellnhuber, who is also Professor for theoretical physics at the University of Potsdam.

The PIK is quoted here as an example of a mathematical modelling approach, conceiving of the world as a cybernetic organism that has to be modelled in terms of positive and negative interactions. Even if PIK is portraying its 'earth system' analysis approach as something quite new, it is actually rooted in the early 70s, when Meadows (Meadows et al., 1972) presented their earth model and a way to calculate the earth's 'Limits to Growth'. The cybernetic modelling approach does not automatically imply manageability, in fact it may likewise lead to the conclusion that cybernetic models are completely unmanageable in the first place[2]. However, in PIK's mission it is the modelling exercise that finally authorises sophisticated earth management.

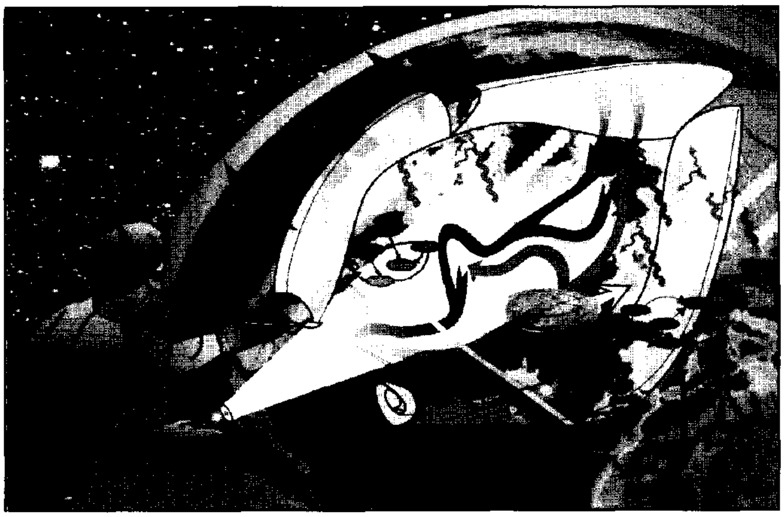

Figure 1. The bio-cybernetic earth model as second Copernian revolution (Schellnhuber, 1999).

Schellnhuber is very optimistic about the relevance of this approach and immodestly considers the 'earth system' analysis to be a second Copernian revolution (Schellnhuber, 1999). According to him the first Copernian revolution – the transformation from a geocentric to a helio-centric world view – was mainly made possible by new optical amplification techniques, "which finally put the Earth in its correct astrophysical context". In the same way the second revolution becomes possible by means of new simulation modelling techniques which finally enable putting the Earth in its correct systems analysis context.

Figure 1 shows the self-image of PIK's revolution going into the earth. A doctor slits open the surface of the earth as if it were the skin of the organism earth. The skin is rolled up and some boxes appear underneath, connected by all kinds of kaleidoscopic arrows. And what a surprise: The world is in fact a bioceybernetic model. That's at least what the picture says.

PIK's organism view on earth is further expanded by two other concepts borrowed from medicine: 'syndrome' and 'symptom'. Both are used to organise the multitude of environmental problems of today's earth in a manner similar to the way in which doctors classify human illnesses. And both are dependent on each other in so far as a syndrome is defined as "a typical cluster of symptoms and their interrelations"[3] (Petschel-Held et al., 1999b). It was the German Advisory Council of Global Change (Wissenschaftlicher Beirat der Bundesregierung Globale Umweltveränderungen, WBGU)[4] that adapted the metaphors for the first time to the environmental context. PIK's director Schellnhuber is a member of WBGU. The approach is described in detail in the WBGU Annual Report 1996 (Jahresgutachten, 1996).

Environmental problems are taken as case studies of syndromes well studied and elaborated. Examples are the Sahel syndrome, standing for overexploitation of soil followed by soil degradation, the Aral Sea syndrome, representing an overuse of water-inflow that results in a nearly disappeared sea and an acidification of soil, or the Disaster syndrome ('Havarie-Syndrom'), that stands for ecological catastrophes like Seveso, Chernobyl, Exxon Valdez or Bophal. The WGBU identifies a total of 16 syndromes of this kind as relevant for global change. They are also seen as "archetypal patterns of Global Change" (Petschel-Held et al., 1999b).

For the PIK-researchers the clustering procedure and the resulting 16 archetypes are interesting, since it is a more feasible endeavour to model only a small number of well investigated cases than the whole world. However, they themselves argue less pragmatically. According to them, the main reason for conceiving of environmental problems in terms of syndromes and symptoms, lies in the request for a common language between scientists coming from different disciplines (Petschel-Held et al., 1999a).

Indeed, the archetypal case studies offer a great opportunity to go beyond disciplinary knowledge. This is especially obvious in Petschel-Held et al. (1999b). The chapter on actors and environment starts with a short description of the role of government in ten different case studies from all over the world – all more or less resembling the Sahel syndrome, the depletion

[1] For further information see http://www.pik-potsdam.de

[2] Vester (1980, p. 24ff) gives the example of Tanaland, a cybernetic model of a fictitious African region, that was developed in the late 70s. In an experiment people where asked to govern Tanaland by deciding on e.g. building dams, attract industry, establish a public health system or by increasing agriculture productivity using pesticides and fertiliser. The outcome was that every test person ran Tanaland into hunger and disaster after a very short period of governing.

[3] An example for two symptoms that interrelate are the increased use of energy and resources and the installation of large scale projects, like dams (Petschel-Held et al., 1999a).

[4] For details see http://www.wbgu.de

of marginal land. The state appears in various roles, as prosecutor of illegal timber cutting, as opener of the land for investors, as the mistrusted government or as the tolerant uninvolved. After that, the same cases are outlined from an ecological viewpoint, describing natural conditions like climate, soil properties and surface water availability. It is precisely this not disciplinarily deformed and rich description of syndromes and case studies that offers the opportunity of a promising common starting point for epistemological interpenetration.

But PIK's researchers proceed in a way which to my understanding directly re-closes the space just opened. A few pages later they try to model the social aspects of the cases with what they call smallholders, which choose between different strategies to survive: agriculture, gathering, hunting or wage labour (Petschel-Held et al., 1999b, p. 272). This means that they 'attach' their explanation of the social aspects only at a micro-level, so that the potential role of social actors, such as the government, switches from being a system component (*box 2*) to being a boundary condition[5]. On the micro level, they look for rules that are valid outside the context, in the sense that they do not depend on the individual cases or on the government. "The question we would like to address is whether the different strategies of all the smallholders [...] obey a general rule or a set of rules. This general rule would represent a major element of the mechanism of the Sahel syndrome, particularly with respect to its social component".

The idea underlying this is meeting the requirements of an universal cybernetic model. In the end, boxes named e.g. LA (labour invested in agriculture activity) or LW (labour invested in wage sector) have to be identified and arrows have to connect them, specifying in which way they influence each other. It is this structure of boxes and arrows, the idea of a context-free set of rules, and the assumption that the choice between strategies is localised in (independent) smallholders, that stipulates what kind of knowledge is included and excluded. Excluded is, for example, that strategies have a meaning and that this meaning depends on a cultural context. The boxes may therefore stand for other things in any area of the world or not be connected in the same way. In fact, what is implicitly assumed is that the meaning of each box and each strategy is the same everywhere. Also, to conceive of actors as stakeholders is a very individualistic viewpoint, that will not reflect how far people's actions depend on the actions of other people, governments or large companies, which in turn again depend on the cultural context in which everything takes place.

From the point of interpenetrating epistemologies, the cybernetic modelling approach works like a filter, through which knowledge from other viewpoints has to pass in order to be included. Whatever is not reducible to the selected and universally valid boxes and arrows does not exist in the earth system. One could paraphrase this way of going beyond disciplinarity as a *master-servant* situation, in which all other disciplinary approaches have to deliver knowledge in a form that matches the requirements of the cybernetic earth model.

Box 2. The three approaches in short

'Earth system' analysis or PIK-approach
Directed by: Prof. Dr. Hans-Joachim Schellnhuber, Director of the Potsdam-Institute for Climate Impact Research (PIK), Germany.
Researchers involved: 'Earth System' Analysis is promoted by Schellnhuber as the common paradigm of the entire PIK. The PIK is a research institute that engages around 150 researchers from various disciplines – the natural as well as the social sciences – working in several sub-projects.
Main disciplines: The system dynamics modelling can be seen as the as the basic 'discipline'.
Founding: Founders of the institute are the Federal Government of Germany and the Federal State of Brandenburg.
Inception: 1992.

History of Matters and Goods
Directed by: Armin Reller, Professor for Chemistry at the University of Augsburg (Germany), and Markus Huppenbauer, Theologian and Moral Philosopher at the University of Zurich.
Researchers involved: Collaboration changes with researchers from the social as well as natural sciences.
Main disciplines: Chemistry, Philosophy and History.
Funding: The research developed without explicit funding for the project.
Inception: 1996.

SYNOIKOS – Sustainability and Urban Design in the Midland Regions of Switzerland
Directed by: Peter Baccini, Professor of Resource and Waste Management and Franz Oswald, Professor of Architecture and City Planning.
Researchers involved: About ten researchers are employed from architecture, the natural and social sciences.
Main disciplines: City planning and substance flow analysis.
Funding: The research is funded by the Alliance for Global Sustainability, the ETH Zurich, the European Union and the Migros Genossenschaftsbund.
Inception: 1996.

History of Matter and Goods: fill the gap between abstract sciences and individual case

Armin Reller, Professor for chemistry at the University of Augsburg in Germany, and Markus Huppenbauer, theologian and moral philosopher at the University of Zurich, developed the History of Matter and Goods approach and published it in 1996 (Huppenhauer and Reller, 1996). In the meantime, Reller has published several case studies in which he applies the approach (Büchi and Reller, 1996), (Reller and Gerstenberger, 1997), (Reller et al., 2000).

According to Huppenbauer and Reller the core problem of environmental research is – quite in accordance with the above critique on the PIK research – to overcome the gap between the a-historical and generalising perspective of the (natural) sciences and the individuality and specificity of each case-study. Hubbenbauer and Reller's approach to overcome this gap is to tell a more complete story: the studied mat-

[5] Petschel-Held et al. (1999b, p. 273) are partly aware of this problem. As concerns the government's role, they suggest to take it into account, "exogeneously when checking the explanatory power of the basic rules of the Sahel Syndrome [...]."

ters and goods are disputed not only from a natural scientific perspective, but also from a historical point of view. The resulting History of Matter and Goods correspondingly tends to highlight "the time-structure of the individual system-environment-interaction [of substances]" (Huppenbauer and Reller, 1996, p. 111)[6].

Huppenbauer and Reller develop the permanent blinding out of individual histories through the natural sciences by means of an example from chemistry, by lime ($CaCO_3$). To illustrate they contrast lime's decontextualised, stoichiometric representations as $CaCO_3$ (standing for the natural scientific perspective) with the various shapes that mineral calcite's will take, depending on the particular growing conditions, like e.g. temperature and concentration (symbolising the historical perspective).

Figure 2 shows how the appearance of $CaCO_3$ differs, depending on the conditions under which it was formed, i.e. depending on its history. Hubbenbauer and Reller conclude from the example to environmental sciences in general that "objects that are appearing in natural scientific theories – what we have termed structures, laws, formulas, equations etc. – do not exist as such in material ecosystems" (ibid., 109)[7]. So, in order to really understand ecosystems and environmental problems one has to look at both sides simultaneously, to the natural scientific, decontextualised representations as well as to "the time-structure of the individual system-environment-interaction".

[6] Original in German: "Deshalb haben wir wiederholt von Geschichten im Sinne von zeitlich strukturierten, individuellen System-Umwelt-Wechselwirkungen gesprochen" (Huppenbauer and Reller 1996).

[7] Original in German: "Die in naturwissenschaftlichen Theorien vorkommenden Objekte – also die von uns so genannten strukturellen Ordnungen, Gesetze, Formeln Gleichungen et cetera – kommen als solche in stofflichen Ökosystemen nicht vor" (Huppenbauer and Reller, 1996).

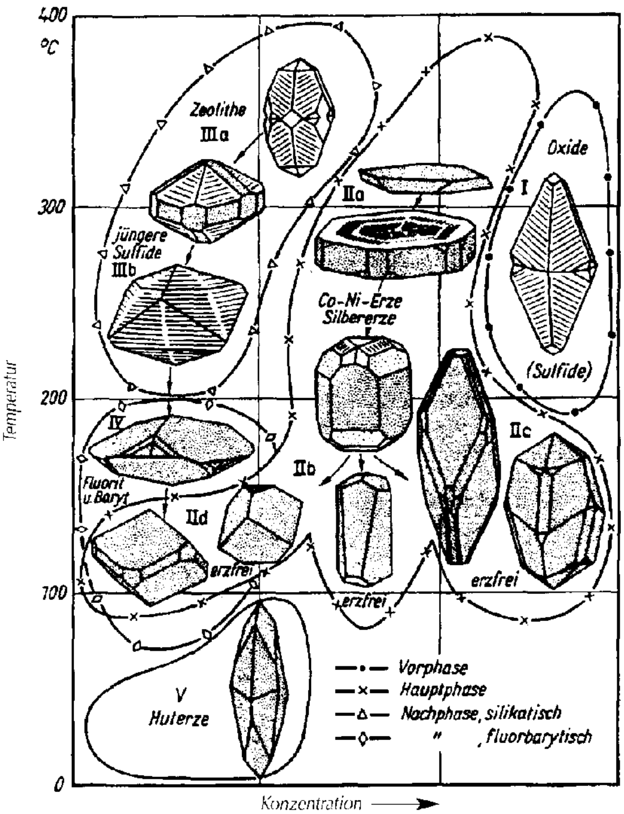

Figure 2. How the history of growth defines the final appearance of $CaCO_3$ (Huppenhauer and Reller, 1996). Original figure from H.J. Rösler: Lehrbuch der Mineralogie, VEB Leipzig (1981), p. 243.

The approach is further exemplified by the cases of cotton (Reller and Gerstenberger, 1997), potatoes (Büchi and Reller, 1976) and silicon (Reller et al., 2000). Unfortunately, in all three examples, the gap that is identified so clearly is not filled. Rather, the histories just introduce the article by telling the story of how (Western) civilisation came to have cotton, potatoes and silicon respectively. But besides placing historical insights alongside chemical and ecological insights, nothing happens. No explicit attempts are made to e.g. bridge between the chemistry of cotton, the history of cotton, the forming of individual cotton plants and the environmental problems that cotton production is professed to induce nowadays.

From my own work in the environmental sciences it is well known to me that to collect and arrange side by side all kinds of information about a topic is a quite prevalent first step. In doing so people (including myself) secretly hope that eventually, in some magic way, all parts will add up to a comprehensive and illuminating grand picture. What I also know is that this last magic step never happens. I assume that the History of Matters and Goods also is rooted in this kind of somehow self-realising holism. The main problem of the approach then is that such self-realisation has as yet not been observed or confirmed. Unless this changes, the History of Matter and Goods may well be called a *deadlock* situation.

Synoikos: sustainable urban planing between morphology and metabolism

Synoikos is a joint project between city-planers and researchers from substances flow analysis that takes place at the Swiss Federal Institute of Technology (ETH) in Zurich. The heads of the project are Peter Baccini, Professor of resource and waste management and Franz Oswald, Professor of architecture and city planning. About ten researchers with different scientific backgrounds are engaged. The research is funded by the Alliance for Global Sustainability, the ETH Zurich, the European Union and the Migros Genossenschaftsbund.

The main thesis of the project is: "The way to a 'sustainable life form for human society' over the coming decades is found in the reorganisation/restructuring of urban-systems" (Baccini and Oswald, 1998, p. 1). The area studied is a typical urban agglomeration in the centre of Switzerland, i.e. not a real city and not the countryside, but something in between. In the Synoikos approach research in this area is always undertaken from two points of view in parallel, as illustrated in *figure 3*.

On the left side of *figure 3* are the urban-planers, who are interested in morphology and metamorphosis, i.e. in the form of the agglomeration and how this form changes over time. They have a bird's-eye view of the landscape. Their main aim is to identify different categories of structures in the landscape (such as lakes and rivers, forests, traffic-systems, urban or agricultural

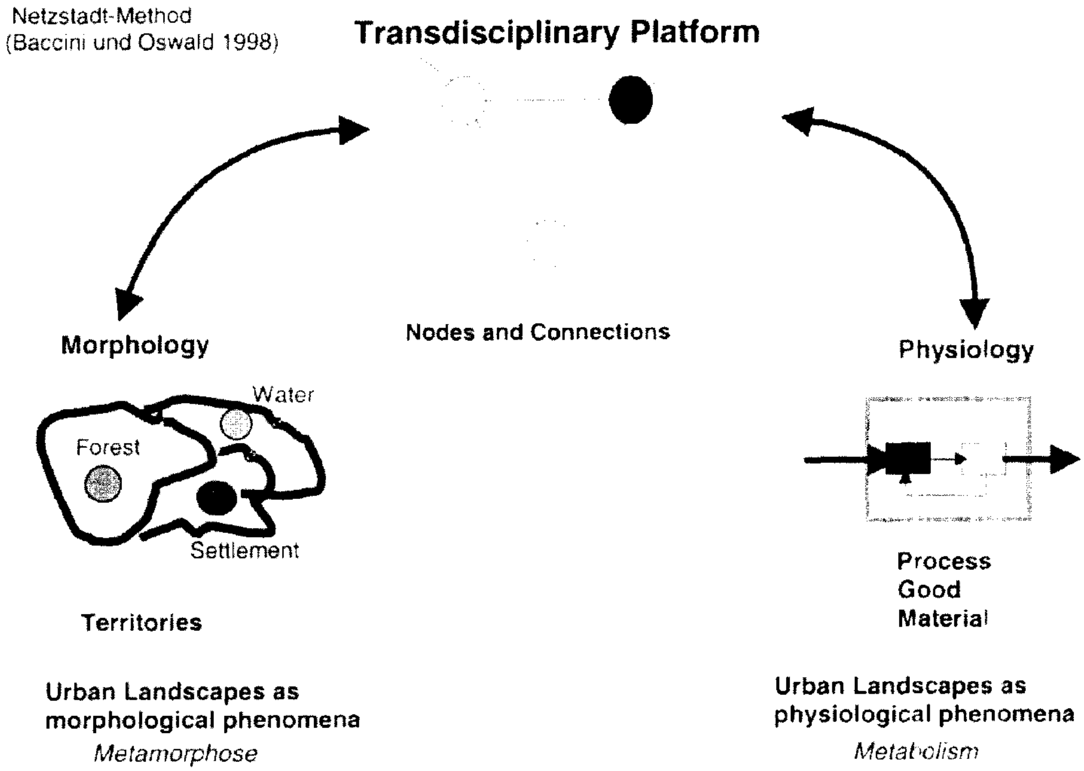

Figure 3. Networks as boundary objects between Morphology and Metabolism.

areas), to map them and to design new maps that show what the future could look like. On the right side of *figure 3* is the substance-flow-analysis. This is a tool to visualise all kind of flows through any kind of system, e.g. the flow of water, food or soap through a particular urban area. In borrowing metaphors (again) from medicine, the system is also seen as an organism and the flows correspondingly are part of the organism's metabolism. The intention of the system flow analysis in the environmental context is mostly to minimise or optimise flows in order to make systems more sustainable.

To investigate the agglomeration from both points of view in parallel, so-called activities are distinguished. Both disciplines are already familiar with the idea of describing actors in terms of activities, such as nourishing, cleaning or transportation and this understanding facilitates their collaboration. To study these activities in the investigated area teams are composed, always bringing together city planers with substance-flow-analysts.

To discuss the transdisciplinarity formed in the Synoikos project I will distinguish the main-project of Synoikos from the sub-projects, which generally concern just one activity alone.

Two of the sub-projects – food and recreation, housing – explicitly illustrate how they experienced transdisciplinarity by means of figures (ibid., 34 & 92). In both cases the procedure is more or less the same: First, the team sets goals for a sustainable agglomeration with regard to land-use (morphology) as well as to the flow of substances (metabolism). Second, the status quo is elaborated by discipline, i.e. from each point of view separately. Third, scenarios of sustainable agglomerations are developed, simultaneously giving an idea of the form and of the metabolism. The third step is seen as the most transdisciplinary, mainly because the results of both points of view influence each other. If e.g. the substance flow researchers rate a project as not sustainable, because it includes a huge increase of a particular substance flow, then the planers have to redesign their plans. The urban planers, on the other hand, may judge a modelled substance flow as unrealisable, because it does not refer to the actual situation and its developmental potentials. To find a metabolically as well as morphologically sustainable form an iterative process of mutual fitting and matching is entered. I will call this kind of going beyond disciplinarity, a *give-and-take* situation between disciplines.

For the main-project the two heads of the Synoikos suggest a second kind of transdisciplinarity in their chapter "Urban Systems as Networks: Building a Transdisciplinary Method"[8]. It is already highlighted by the network in *figure 3*, which bridges between morphology and metabolism. Networks, seen quite abstractly as interacting nods, become the new basic model for Synoikos. This is the case, because the network-model at the same time can be understood morphologically and metabolically. For the urban planners the nods are

[8] Original in German: "Urbane Systeme als Netze: Aufbau einer transdisziplinären Methode" (Baccini and Oswald 1998).

compressed urban areas, and the interactions are e.g. traffic lines or rivers. In the eyes of the systems flow researcher, the nods are so-called processes and the lines indicate material fluxes between them. The network-model is still under construction and will be further elaborated in the next phase of the Synoikos project.

From the point of view of 'far beyond disciplines' something new and extraordinary is happening here. With the network model, Baccini and Oswald have found a metaphor that is accessible from a morphological as well as from a metabolical point of view. In addition, the network-model so far belongs neither to urban planning nor to substance-flow-analysis alone. This, in turn, signifies that it has no concrete meaning in both scientific fields and therefore is open for new definitions. Baccini and Oswald have established a common base independent from their original disciplines. I will call this a *new commonality*-situation.

After having shown how the core environmental problem is conceived and solved differently by each method, and how knowledge from different disciplines is brought together, I will now further distinguish the disciplinary collaboration by adopting boundary concepts from the social studies of science.

Qualifying the way to go (far) beyond disciplinarity

Following the ideas of Gieryn (1983, 1995), Star and Griesemer (1989) and especially Thompson Klein (1996) transdisciplinarity has a lot to do with boundaries, boundary work and boundary objects. These terms subsequently will be explained briefly and then linked with the transdisciplinary research methods described in section 3.

The term boundary has to be viewed in the wider context of the social studies of science and, more specifically, from a cultural-anthropological perspective. Science, or the knowledge produced by science respectively, is understood as a landscape. In this landscape of knowledge different disciplines exist (seen as tribes) occupying territories of their own. A discipline's territory is the field of knowledge, in which the discipline disposes of cognitive authority and epistemical primacy respectively. This is generally the case if questions concerning a specific part of knowledge are posed to a specific branch of science, e.g. questions about poisoning to toxicologists, questions about individual human behaviour to psychologists or questions about the meaning of life to philosophers. Boundary work now describes the struggle for epistemical primacy at the boundary of neighbouring territories.

Table II summarises the way in which boundary work is done in the methods that were introduced in section 3. The second column summarises the collaboration circumscribed above. The third column summarises the boundary work that is undertaken by each method.

PIK's 'Earth System' Analysis approach was called a master-servant situation. Sociological knowledge has to be transformed in a way that permits it to enter the cybernetic earth model. In terms of boundary work the tribe of earth system modellers here wins the struggle for epistemical primacy. The territory, within which the question is disputed how knowledge from different disciplines has to be integrated, is successfully occupied.

In the case of History of Matter and Goods there is now exchange and accordingly no struggle for primacy.

Within the Synoikos example the two cases of subprojects and main project have to be distinguished. The sub-projects undertake something of a knowledge exchange among equals, without ever touching the question of cognitive authority. Each discipline owns its territory, the frontiers are clear. If the substance flow tribe says 'not sustainable', then the planners believe it. And if the planers say 'not feasible' then the substance flow tribe goes back to the models.

The case is different for the main project. None of the tribes have had to do with the network-model previously, which accordingly presents new grounds. Both tribes now include the new grounds into their territories at the same time and in this way are able to share the epistemical primacy.

Table II also enumerates the boundary objects that are used. Boundary objects are objects that lie exactly on the boundary of neighbouring territories, such as e.g. the above mentioned network-model in the Synoikos main-project.

Table II. Type of disciplinary collaboration from a boundary perspective.

	The situation is characterised as...	*Who enlarges epistemical primacy?*	*boundary objects are...*	*...disciplinarity*
'Earth System' Analysis	master-slave	cybernetic model	syndromes and earth-model	beyond
History of Matter and Goods	deadlock	nobody (no struggle)	matter and goods	no exchange
Synoikos sub-projects	give-and-take	nobody (exchange under equals)	activities in a specific area	beyond
Synoikos main project	new commonality	both	network model	far beyond

Boundary objects enable bringing people from different tribes (from different social worlds in the original text) together and letting them realise a common project. To fulfil the requirements of each tribe, boundary objects have to be "plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989, p. 398).

Boundary objects are not new to environmental research. Rather, the problem-orientation of transdisciplinarity (as well as the corresponding orientation to case studies) in a way guarantees that a common object of concern will always be at the core of research. But that is not the point. The point to make here is that boundary-objects are e.g. able to bring diverse disciplinary interests together without any obligation to find a common understanding or to mutually interpenetrate disciplinary epistemologies. As column 4 and 5 in *table II* show, boundary objects accordingly do not necessarily induce going (far) beyond disciplinarity. However, the example of the network model indicates that boundary objects at the same time can be key elements to going far beyond disciplinarity. So even if boundary objects do not guarantee going far beyond disciplinarity, they nevertheless still enable doing so. Therefore, transdisciplinary researchers should keep them in mind and try to use them as research tools more systematically.

Conclusion

The main objective of this paper was to learn about the way in which transdisciplinary research methods amalgamate disciplinary epistemologies from the natural and social sciences. All approaches studied, the 'Earth System' Analysis (Schellnhuber, 1999), the History of Matter and Goods (Huppenbauer and Reller, 1996) and Synoikos (Baccini and Oswald, 1998) follow their own approach in handling that problem. In the PIK-approach it is the search for a universally valid cybernetic model that filters the kind of knowledge that can be absorbed. Assuming that knowledge from the natural sciences is more often available in form of quantitatively interacting parameters than knowledge from the social sciences, the cybernetic model approach runs the risk of being lopsided. It prevents especially the context-sensitive and qualitative social sciences from entering the debate on global change. It is the History of Matter and Goods that precisely intends to give back some of this missing individuality to the de-contextualised knowledge from the natural sciences. But it does not go any further than to place the story of a good alongside its chemical properties and environmental impacts. Though the approach does not exclude any kind of knowledge, it does not either give an indication on how to amalgamate the knowledge from different fields. It just ends up as a rich description. The Synoikos approach appears to be the most promising. Transdisciplinary collaboration is realised as a repeated exchange between urban planers and substance flow researchers, or leads to new commonalities that can be used as common frameworks.

To construct or to explore new commonalities in transdisciplinary research projects is certainly an idea that is worth further exploration. Since new commonalities are like terra incognita for the respective disciplines, they invite being addressed in a way that can be agreed upon by different disciplines. However, for the two cultures of the natural and social sciences, this is likely to be more complicated than for planers and modellers. I am convinced that in the long run the gap between the two cultures can only be bridged by new commonalities that offer acceptable 'insights' for both sides. They will have to allow knowledge of a context-free and timeless form to co-exist together with highly contextualised knowledge. Also, they will need to allow addressing issues as really 'real' and at the same time as entirely socially constructed. The problems that may arise when having to try to imagine such paradoxical commonalities should not be a reason for frustration. Rather, the paradox may be seen as hinting at some really exciting concepts that still remain to be developed.

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