Disentangling Transdisciplinarity:
An Analysis of Knowledge Integration in Problem-Oriented Research

Wolfgang Zierhofer and Paul Burger

Within the discourse promoting transdisciplinary research (TDR), also referred to as Mode 2 science, it is often claimed that scientifically coping with urgent life-world problems calls for interdisciplinary participatory research (or TDR), and that this represents a new mode of knowledge production. Although we look upon TDR as a fertile innovation, we have epistemological and methodological concerns in treating TDR as a (singular) new mode of knowledge production. Hence, our paper attempts to contribute to clarifying the meaning of TDR from an epistemological and methodological perspective. We develop a conceptual scheme for the analysis of knowledge production in problem-oriented research, which is subsequently applied to an empirical analysis of 16 transdisciplinary research projects. In our analysis, we focus upon forms of knowledge integration and participation. The results indicate that, from an epistemological point of view, TDR does not represent a specific mode of knowledge production, but a rather heterogeneous conglomeration of different research activities. In order to evaluate the epistemic potential of TDR, we conclude that it would be wise to disentangle it methodologically into various types of research objectives and related research instruments.

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In environmental and sustainability science the concept of 'transdisciplinary research' (TDR) has recently received increasingly wide recognition. Although there are a remarkable variety of formal and informal definitions of TDR (see Brand, 2000; Thompson Klein et al., 2001; Nowotny et al.; 2001; Scholz and Tietje, 2002; Balsiger, 2004; Max-Neef, 2005; Stokols et al., 2003; 2005), the majority of proposals concentrate on three common denominators: TDR is said to be oriented towards *life-world problems* (thus initially non-scientific problems), to have a *multi-* or *interdisciplinary* working mode, and to be complemented by some form of *participation* of stakeholders or affected people in research with regard to the issue in question.

Two streams of discussion nurture a positive attitude towards TDR. The first one is related to a broader debate on the renewal of the contract between science and society at large (Maasen, 2007; see also Weingart, 2001). In this respect, the concept of science shifting paradigmatically from the traditional Mode 1 of knowledge production to a new, transdisciplinary Mode 2 (Gibbons et al., 1994, Nowotny et al. 2001) or a post-normal science (Funtowicz and Ravetz, 1993) has become generally known. In contrast to Mode 1, Mode 2 science is said to be mainly driven by problems of the lay population and to be more sensitive to the context of knowledge application, as expressed by the ideal of producing 'socially robust knowledge' (Nowotny et al., 2001: 166ff.). As is often the case with fashionable words, 'transdisciplinarity' is used with different meanings (see Bruun et al., 2005: 30ff.). Stokols et al. (2003; 2005), for example, characterize a strong version of interdisciplinary cooperation as transdisciplinarity. For our needs, however, it is important to note that this meaning ('across the sciences') has to be distinguished from the way it is used within Mode 2 discussions. For the latter, some active integration of societal actors is decisive.

The second pro TDR stream of discussion is informed by reflections of scholars on their own transdisciplinary projects (e.g. Brand, 2000; Hurni and Wiesmann, 2001; Scholz et al., 2000; Tress et al., 2003; Truffer, 2003; Wiek, 2005; Posch and Scholz, 2006). They are especially motivated to strengthen and highlight *participation* within research, arguing that science should not only describe or explain the world, but also directly contribute to social transformation (CASS and ProClim 1997). To do this, science has to involve societal actors. Accordingly, it is often claimed that TDR offers an epistemic and a societal surplus in contrast to traditional science. In the eyes of these authors, TDR is particularly well suited for solving societal problems. Furthermore, the debate on TDR reveals a strong tendency towards normative topics, such as democratization of science, rationalization of policy decisions, public acceptance of innovations, and taking into account of public goods for example. Häberli et al. (2001: 7) summarize this positive attitude towards TDR as follows:

> Transdisciplinarity is a new form of learning and problem solving involving cooperation among different parts of society and academia in order to meet complex challenges of society. Transdisciplinary research starts from tangible, real-world problems. […] Ideally, everyone who has something to say about a particular problem and is willing to participate can play a role. Through mutual learning, the knowledge of all participants is enhanced […]. The sum of this knowledge will be greater than the knowledge of any single partner. In the process, the bias of each perspective will also be minimized.

According to this characterization and the above-mentioned literature, TDR is thus passed off as a scientific approach which is particularly well suited to meet life-world problems, and which produces a series of benefits, such as so-called 'socially robust knowledge'. According to the specific challenges for transdisciplinary research projects—e.g. different types of cooperation, handling of heterogeneous interests—the literature rightly pays strong attention to project management (Häberli and Grossenbacher-Mansuy, 1998; Loibl, 2005; Defila et al., 2006) and to guidelines for the

evaluation of transdisciplinary projects (Bergmann et al., 2005; Defila and Di Guilio, 1999; Stoll-Kleemann and Pohl, 2007; Zierhofer, 2003).

Unfortunately, methodological or epistemological considerations and particularly empirical analyses of TDR projects have only occasionally entered the discussion (Balsiger, 2004; Blättel-Mink and Kastenholz, 2005; Bruun et al., 2005; Burger, 2005; Burger and Kamber, 2003; Gethmann and Lingner, 2002; Hirsch Hadorn et al., 2002; Scholz and Tietje, 2002). The claims regarding the epistemic and social power of TDR have so far not been subjected to systematic epistemological reflection and related empirical analysis.

It is our aim to contribute to a clarification of the epistemic potential of TDR. In particular, we strive to add conceptual and empirical evidence in an attempt to answer the question of whether TDR really represents a single type of knowledge production. We will suggest that TDR should be considered rather a class of epistemically and methodologically heterogeneous research activities which are only formally unified by the two general properties 'interdisciplinary' and 'participatory'.

In general, TDR is regarded as a specific life-world problem-oriented research domain. But what does this mean? We will argue that in epistemological terms this means that TDR aims to inform and rationalize human actions by dealing with action-related knowledge desiderata. We take it as our starting point that research pursues specific epistemic ends by applying specific forms of investigation or methods (section 2). An epistemic end is what a research process strives to deliver, that is for example, an explanation or an interpretation. Accordingly, if TDR is a new type of knowledge production, we must be able to identify a set of characteristic epistemic ends of TDR. Sections 3 and 4 conceptually develop a typology of epistemic objectives of TDR, which represent the basic intuition of TDR as 'problem-oriented science'.

Our conceptually developed typology also serves as an analytic scheme to gain empirical information of knowledge production in TDR. In our subsequent empirical analysis of knowledge production in 16 transdisciplinary research projects and programs (section 5), our focus is on the relations between the project goals, forms of knowledge integration and forms of participation. In section 6 we will discuss the findings, and we will claim that they add evidence against the conception of TDR as a unified mode of knowledge production. We conclude with some additional methodological reflections on TDR.

Transdisciplinary research – ends and forms

We take it as our starting point that TDR is a fertile scientific approach that, following its standard characterization (Häberli et al., 2001: 7; see also Blättel-Mink and Kastenholz, 2005), provides a series of interesting criteria. TDR is said to:

- contribute to the solution of tangible real-world problems.
- have an orientation towards application of results in practice.
- meet complex challenges of society.
- contribute to mutual learning and enhance knowledge of all participants.
- minimize the bias of the perspectives involved.

According to the Mode 2 thesis, TDR is a new mode of knowledge production. Unfortunately, the locution 'mode of knowledge production' is ambiguous. It may express how TDR is carried out,

hence addressing its form. However, it may also express its cognitive functions or epistemic ends, hence addressing the performance of TDR. The list above clearly states the intended epistemic ends of TDR. Its general form is normally defined by interdisciplinary and participatory research settings. However, the relation between this form and the above listed functions is not yet sufficiently clarified in the literature on TDR. First, it is not yet well established what these claimed performances amount to in epistemic terms. Second, it remains to be analyzed in what respect 'interdisciplinary' and 'participatory' might amount to one particular form of research or if TDR is by contrast a term representing a variety of research forms. Third, the epistemic relation between TDR as a form of research and its epistemic ends is poorly clarified, especially regarding the impact of participation on knowledge production. Hence the relations between research ends and research means are on the one hand crucial for assessing the epistemic potential of TDR, but on the other hand not well understood. This is why we propose to disentangle TDR into 'elementary' ways of knowledge production, that is, types of knowledge desiderata and related research methods.

Before working out our conceptual proposal we would like to add a few preliminary clarifications. First, we would like to stress the difference between transdisciplinary projects in general and transdisciplinary *research* in particular, to which we will restrict this article. Consultancy, for instance, can meet all the requirements for transdisciplinary scientific endeavours described above, but it does not pursue primarily epistemic ends. Its purpose is the synthesis, interpretation and application of existing knowledge with respect to certain issues, but not necessarily the production of new stocks of knowledge. As a consequence, consulting is not subjected to the same kind of methodological standards as research (see Stokols et al., 2003 for a similar distinction). Second, interdisciplinarity as a constitutive part of TDR is itself a wide and complex field (Klein, 1990). Since in this text our interest is in epistemological issues and knowledge production, we define interdisciplinarity as research cooperation between different disciplines heading towards knowledge integration (Max-Neef, 2005: 7). In the following our focus will be upon knowledge integration related to the analysis of life-world problems. Third, when assessing the epistemic potential of TDR, it is imperative to regard TDR as a form of research that may serve a broad range of project ends, many of which do not necessarily qualify as species of knowledge production. Fourth, although 'societal problem solving' is taken as a distinctive property of TDR, expressing an *end* of TDR, interdisciplinarity and participation are the two key features of its *form*. Only when we assess TDR in terms of relations between epistemic ends and means or forms of research will we be able to determine its epistemic potential and to discuss its methodological status.

TDR as problem-oriented research

We take it as our task to clarify whether dealing with societal problems—the core end of TDR—really implies specific knowledge desiderata. As we already pointed to and as will become evident in the empirical part, TD projects may pursue other purposes apart from just research. These purposes may even be imperative in establishing fair partnerships between scientists and stakeholders. Nevertheless, some of the above-

listed performances are not typical functions of science, but of other societal subsystems, particularly politics, administration and economy. To foster mutual learning, to enhance the knowledge of participants, to minimize the bias of the involved perspectives and to have an orientation towards practice are demands which are not derived from *scientific* knowledge desiderata and which do not necessarily ask for genuine research. Although they may be legitimate objectives for projects involving scientists and other actors, they are first and foremost pedagogical, communicative and political goals. On the other hand, contributions to the solution of (particularly complex) societal problems may require new systematic and empirical knowledge.

Arguably, one might insist that all scientific knowledge production, whatever its subject, is problem-oriented and that, accordingly, 'problem-orientation' cannot function as a criterion for distinguishing different modes of research. Yet, when talking of problem-oriented research, advocates of TDR generally refer to life-world problems, which, so the argument goes, are different from genuinely scientific problems and call for a specific type of knowledge production. Reference to 'life-world problems' alone, however, will not suffice to establish a specific domain of epistemic objectives. A comparison between astronomy and cancer research, for instance, reveals that both are basic and Mode 1 sciences heading for a theoretical advancement in their field. But while astronomy is mainly driven by the motivation to develop astronomic and physical theory, cancer research is mainly motivated by the need to develop early diagnoses, therapies and prevention strategies. Although theory formation in cancer research is instrumental with respect to a life-world problem, cancer research is not usually treated as a member of the TDR family. Of course, patients are objects of research and their problems have to be considered; yet, the medical understanding of different species of cancer is not constituted by the knowledge, the interests or the cognitive activities of the affected persons.

If 'life-world problem' is still too vague we should look for a specifying criterion. In ordinary language, for example, we speak of a problem if a situation cannot be mastered in the expected, habitual or routine manner. In order to pursue ends successfully in spite of difficulties, some extraordinary input is needed, whether in the form of physical or financial means, or of social support or know-how. Research will only contribute directly to problem solving if missing knowledge is constitutive for the problem. Problem-oriented research may be interpreted as aiming to reduce knowledge gaps which hinder some stakeholders or institutions to pursue certain actions. We propose to go along this line of reasoning in order to characterize the potential epistemic performance of TDR. Problem-oriented research in this sense is driven by knowledge desiderata, which are derived from missing knowledge for action. Lack of disciplinary knowledge, which is regarded as the main driving force in Mode 1 research may also play a role, but only insofar as it is relevant to those actions in question.

Our proposal for the specific meaning of 'societal problem-orientation' as 'knowledge for action' does not only capture the intentions of the advocates of TDR, it also leads us to well founded theoretical conceptualizations. Within social scientific action theories (like those of M. Weber, A. Schütz, A. Giddens and J. Habermas), it is a standard to further differentiate the notion of action into

'situation', 'goal', 'means', 'consequences' and similar categories (Werlen, 1993: 11ff.; Zierhofer, 2002: 93ff.). Knowledge barriers for actions may emerge from any of these structural components, including controversial issues and diverging interests. Since social scientific research systematizes, analyzes, and assesses activities or social structures that are reproduced by activities, the specific contribution of problem-oriented research may be regarded as the *rationalization* of activities (Burger and Kamber, 2003). Problem-oriented research in this sense aims to give actors additional means at hand by investigating problematic cognitive aspects of their intended actions. Accordingly, problem-oriented research seeks to elaborate relevant information, a spectrum of options, as well as pros and cons regarding specific options.

Consequently, it appears that this type of research orientation differs from Mode 1 knowledge production in at least two respects. First, knowledge production is linked to the objectives and cognitive problems of extra-scientific actors. In contrast to theory-driven science, in problem-oriented research scientists are not fully autonomous in formulating knowledge desiderata and epistemic ends; they will often negotiate research goals with interested actors. Second, problem-oriented and theory-driven research may operate with different schemes of knowledge integration. While Mode 1 research aims above all to produce coherent and consistent knowledge within a theoretical context, problem-oriented research will additionally strive for integrating knowledge with respect to certain human actions. By consequence, it will have to define its specific relation to the societal actors in question.

Accordingly, our first step in developing a conceptual scheme for analyzing the epistemic potentials of TDR may be summarized in the following way: while interdisciplinarity and participation are the features that define TDR as a *form of research*, we take problem-orientation in the sense of 'knowledge for action' as its *epistemic end*. On that background we will now proceed by systematically unfolding the relations between different elements of actions and knowledge desiderata. These relations, then, will build the core of a concept of problem-orientation, which we will use subsequently for an analysis of transdisciplinary research projects.

Towards a conceptual scheme for problem-oriented research

Because knowledge barriers can arise with respect to situations, goals, means, and consequences, the distinction of constitutive elements of actions allows a first classification of types of possible knowledge desiderata. Knowledge may be missing regarding facts which constitute the situation of an action or its consequences, but also with respect to preferences of actors or the consistency of priorities. As a consequence, problem-oriented research has to elaborate knowledge on a factual and an evaluative (or axiological) level. Table 1 applies this distinction to a systematization of knowledge desiderata, which may emerge from life-world problems: on the horizontal dimension the various elements of action are distinguished, and the vertical dimension distinguishes between factual issues and valuations.

Let us work with an example. The government of a township has to cope with frequent traffic jams. The traffic volume as such and the behavioural habits of the inhabitants belong to the situation. Some aspects of the traffic situation are

Table 1: Matrix of possible scientific knowledge desiderata.

	Elements of actions:			
	Situation:	**Goals:**	**Means:**	**Consequences:**
States of affairs:	Relevant conditions with respect to certain actions	Goals and criteria	Possible means to pursue the goals	Expectable or realized effects of certain means or actions
Valuation:	Preferences for elements of the situation according to certain criteria	Preferences for specific goals according to certain criteria	Preferences for specific means according to certain criteria	Preferences for specific consequences according to certain criteria

regarded as desirable, others as undesirable. Therefore, the aim might be to mitigate the undesired effects, and to choose effective means with few undesirable side effects. Typical knowledge desiderata concern the real situation, the goals or preferences of the population, the coherence of objectives, the available means or the potential consequences of measures and their evaluation by the population. The matrix of knowledge desiderata offers a way to *organize the epistemic contents* of attempts to solve problems. Not every research contribution will have to execute investigations in all of these eight fields, but every investigation that claims to be a contribution to some problem-solving must generate knowledge within at least one of these fields and with a thematic reference to the overall context.

Every performed action is based on a cognitive synthesis of goals, and on an interpretation of the situation, the perceived means at hand and the expected consequences, thus on the four analytic features of actions. Therefore, problem-oriented scientific analysis may not only fill knowledge gaps but also strengthen the coherence between the elements of the action(s) in question. Moreover, since various disciplines may contribute specific information by way of facts (physical and social conditions, explanations of processes and of cause-effect relations), value related arguments (e.g. cost-benefit relations, ethical considerations) and different perspectives (e.g. alternative terminologies, deconstruction), this analytical understanding of actions also offers a way to *organize the integration of different kinds of knowledge*.

Accordingly, we take contributions to the informing and the rationalizing of actions in their societal context to be the main performance of problem-oriented research, and by implication, also of TDR. To rationalize the coping- and problem-solving strategies of extra-scientific actors implies that their goals, interests and values, and even their understanding of the case, are taken into account. Insofar, problem-oriented research may depend in various ways on the knowledge of the involved actors. This raises the question of how to incorporate their knowledge or even themselves into research. Our focus on the elements of actions (as outlined in table 1) also opens a way to a methodological interpretation of incorporating 'local knowledge' or 'socially distributed knowledge' (Gibbons et al., 1994: 4) in research, two features which are commonly regarded as characteristic of Mode 2 science.

We thus suggest that the core claims implied by the 'problem-orientation' of TDR may be expressed by a system of related cognitive components which are constitutive for informed actions or decisions. *Integrative* knowledge production according to this scheme indeed

surpasses traditional conceptions of science. Moreover, this approach enables us to gain a precise epistemological interpretation of what the production of "goal-" and "transformation-knowledge" (CASS 1997)—which is often presented as the central function and distinctive feature of TDR—actually involves.

Transdisciplinary, problem-oriented research in practice

In the following we will apply the conceptual scheme elaborated above in an empirical analysis of 16 transdisciplinary research projects and programs. Our focus is upon the relation between knowledge desiderata or research ends on the one hand, and forms of knowledge integration, as well as forms of participation on the other hand. Although a sample of 16 cases does not allow any statistical analyses, the number is large enough to discuss the putative methodological homogeneity of TDR. Our analysis is part of an empirical research project on 'Knowledge Production in Transdisciplinary Research Practice', which we carried out from June 2003 to June 2005 in collaboration with Sabine Maasen and Oliver Lieven at the University of Basel.

As we outlined above, the notion of TDR is understood in manifold ways, and it covers a broad spectrum of project types. The selection of projects for our investigation is not statistically representative, but aims to represent cases out of the broad spectrum of project constellations. First, we confined ourselves to the field of environmental and sustainability studies. In order to avoid presupposing a too specific interpretation of transdisciplinarity, we selected projects that involved a collaboration of scientists of different disciplines, as well as participation of non-scientific partners. Since projects which fulfil these formal criteria of transdisciplinarity are nowhere registered, their number is unknown and it is impossible to draw a systematic sample of the population. Therefore, we had to rely on personal contacts in order to find projects that vary considerably in size, project or program design as well as research themes. Within the limits of our resources we were finally able to analyze eleven projects and programs from Switzerland, three from Austria and two from Germany (see Table 2).

None of the investigated projects is confined exclusively to research. The projects investigate topics like sustainable regional development or coping with development problems in Europe, as well as third world countries on various scales; they perform life cycle analyses and impact analyses in respect to product options; they deal with development of environmentally sound technical processes and products or with establishing an eco-label; they investigate landscape change and landscape management; they evaluate impacts on ecosystems and develop corresponding coping strategies. Quite often the objectives of the projects encompass not only research ends, but also aim to initiate and accompany processes of planning and of political decision-making, or they even get involved in mediating conflicting interests. Interdisciplinary cooperation within these projects varies from cooperation among a few natural sciences (e.g. biology and geology) to complex interactions across many fields of natural and social sciences, humanities and engineering. The size of the projects ranges from small groups of scientists cooperating with a handful of specific partners from a specific administrative system to national research programs involving many hundreds of scientists

Table 2: Brief characterization of the sample of transdisciplinary projects and program.

1) Restoration of an ecosystem, involving mainly natural scientists and authorities working on the feasibility, but also some social scientific analysis regarding the acceptance of intended measures by the local population.	9) Analysis of the negotiation process and the public communication regarding the search for a waste-deposit site; in order to develop recommendations, the project team worked together with the ministry and with involved politicians and experts.
2) A project on the promotion of education on sustainable development through collaboration between schools and enterprises; the project aimed to establish an institutional setting by participation of teachers and education authorities.	10) Search for an efficient, symbiotic regional energy production and consumption among a few large and very energy-consuming industries; technical, economical and sociological analyses, participation of managers.
3) This project modelled the quantitative relations between health-threatening emission and the behavioural patterns of a regional population; cooperation with the authorities, particularly for executing measurements.	11) This project aimed to develop scenarios for regional development in economic, ecological and socio-cultural terms; the analysis was conducted as a participative process involving authorities, many stakeholders from the regional population and experts.
4) Various recreational activities have an impact on the regional level; in cooperation mainly with authorities, but also with interest groups, this project identified and quantified the impacts, developed coping strategies and evaluated their effectiveness.	12) Developing the institutional framework and the accrediting procedure of an eco-label; natural scientific research on relevant causal relations and parameters, combined with intensive negotiations among producers, authorities and environmental NGOs.
5) Forestry, farming and tourism may hinder the fragile reproduction of alpine forests, which serve as shelters against avalanches and falling rocks. Systematic workshops with stakeholders analyzed the situation and identified possible measures.	13) Research on and conceptual development of an alternative infrastructure system; collaboration with producers and consumers mainly for test runs and pilot projects.
6) Through a series of consecutive projects an industrial production chain should be switched from synthetic to bio-organic raw materials; this required close collaborations with enterprises, particularly with their managers and technicians.	14) Project aiming to understand an ecosystem change and the decline of certain species; a group of scientists, authorities, businesses and NGOs established a network among relevant existing projects and initiated an exchange on a set of hypotheses.
7) This project modelled the effect on the cultural landscape and the regional economy for two contrary scenarios of producing a typical product of daily consumption; they collaborated with firms of the production chain and consumers.	15) A program on sustainable development and vulnerability in the third world; international cooperation among research institutions and authorities on the program level, extensive involvement of the local populations on the level of individual modules and projects.
8) A program on the sustainable development of settlement-structures, traffics networks and landscapes in agglomerations; focus on identifying determining factors and on steering strategies; collaboration mainly with authorities.	16) A national program on landscape change in a European country; collaboration among scientists, authorities and politicians in the initial phase of the program; various forms of participation on the project level as a key intention of the program.

and even more representatives from civil society and authorities. Some of the projects are composed of coordinated modules, and some are programs that bundle projects thematically without integrating them on the operational level.

In order to depict relations between knowledge desiderata and the specific transdisciplinary organization of the project in question, we applied a systematic analysis of documents that were constitutive for the project or program, such as research proposals, intermediary and final reports, and scholarly publications. This qualitative content analysis operated with sets of variables designed to capture the following features of the projects: problem-orientation, specific knowledge desiderata, their relation to scientific and non-scientific actors, all relevant project activities, particularly labour division and related modes of collaboration and cooperation, research steps, important elements of the project environment (such as boards and steering groups or a program frame for project modules), intended project goals and products, research methods applied, as well as aspects of success or failure. In order to confirm, clarify and deepen the analysis of documents, it was complemented by semi-structured interviews with a project leader on similar themes. Moreover, to make the projects

comparable, we applied a template with defined categories to structure the information. Subsequently, we analyzed this data in respect of the relation between knowledge desiderata (according to Table 1) on the one hand, and knowledge integration and participation on the other hand. In the following sections we will discuss these results, which are also represented in the tables 3 and 4. With the exception of goals, which are analyzed only in evaluative terms, all elements of the action structure (according to Table 1) are represented from a factual and an evaluative point of view in tables 3 and 4. In addition, we also indicate the difference between projects in the strict sense and programs (no. 8, 15 and 16).

Knowledge desiderata

We will first turn to knowledge desiderata as the core objective and very basis of any scientific endeavour. Applying the system of problem-oriented research (see Table 1) to the projects studied results in a Table 3, which shows for each of them the kinds of knowledge desiderata that guide the research. Desiderata, which refer to factual knowledge (What is the case?), are indicated by a mid-grey field. Those referring to sorts of valuations (What is good or preferable?) are represented in dark grey. White fields indicate that a project did not investigate that element of action.

All projects strive for an analysis of the problem situation. Some projects search just for very specific information which fills a gap in the otherwise sufficiently known 'system', while others strive for a systematic representation of the situation as a whole. With the exception of project no. 3, which aims to offer the authorities a quantification of emission-relevant factors, all projects and programs also intend either an assessment of means or of consequences (or of both). This means that most projects take the factual and the evaluative level into account. Since the clarification of facts is always a precondition for their valuation, we find more white fields for the valuation of means or consequences than for their establishment.

We observe many empty (white) fields regarding the valuation of the problem context and, above all, the assessment of goals. This means that the majority of knowledge desiderata are articulated within a rather purpose-rational framework: the goals are regarded as known or given, and they are rarely considered as needing clarification. Hence the focus

Table 3: Knowledge desiderata and methods of knowledge integration in transdisciplinary projects and programs.

Kinds of Knowledge Desiderata			= Facts								= Valuations						
Integrative Methods		o	= Forms of Systems Analysis							Δ	= Forms of Scenario Analysis						
Project	Program	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Situation		o		o		o		o			o	o					
Valuation of situation						o											
Goals												Δ					
Means		o				o					o						
Valuation of means						o					o						
Consequences		o						Δ	Δ			Δ		Δ			
Valuation of consequences									Δ			Δ					

of investigation is on the availability of means and their adequacy, and only to a lesser extent on their desirability or legitimacy. However, projects no. 1 and 11 and particularly the programs no. 8, 15 and 16, which invest in the evaluation of goals of stakeholders, also apply some form of participation of stakeholders for that purpose.

Methods of knowledge integration

Heterogeneous knowledge desiderata lead to heterogeneous research results, which need to be integrated somehow in order to gain a comprehensive account. If we now, as a second step, take a look at the employment of methods or instruments especially designed for the integration of stocks of knowledge, our set of 16 projects and programs reveals the use of two types, namely forms of systems analysis and forms of scenario analysis. They are represented in Table 3 by squares and triangles, respectively. Systems analysis refers to methods which represent a delimited issue or case in respect of certain criteria as a model, systematically disclosing internal relations and relations to its environment. Often scenario analysis is based upon such system models. It analyzes the spectrum and the preferability of potential developments of the case, which may be useful for the assessment of decision options and their consequences. Thus, 'system' and 'scenario' are to be understood in this context as schemes, which serve to represent a case and its potential development in an organized way. Because their conceptual basis is purely formal, they can be applied to almost any kind of empirical case or development. This turns these schemes into instruments which allow the integration of knowledge from various academic disciplines and fields of practical experience.

System modelling and scenario analysis may take many different concrete shapes. In our examples, the range of system models covers stochastic-causal relations between emissions and mortality (no. 3), material flows in industrial production chains (no. 7), strategies of regional energy distribution among industries (no. 10), or regional development involving stakeholders and other representatives of the population (no. 1, 5, 11). Project no. 13 developed purely technical scenarios for radical innovation in a major infrastructure system. Projects no. 7, 8, and 11 developed scenarios of regional development and landscape change. For this purpose a sample of the affected population and experts were invited to participate in workshops. In the end only project no. 11 applied a rigorous (partly quantitative) methodology of participatory scenario analysis, while no. 7 and 8 relied more on consensus seeking through structured discussions. Although systems analysis is primarily suited for analyzing situations or for testing means-end relation—whereas scenario analysis is designed to assess goals and consequences of measures—in our sample both kinds of methods have been used for both fact-related, as well as evaluative investigations.

As Table 3 shows, only eight projects applied particular methods of knowledge integration. Among these, systems analysis is more frequent than scenario analysis. Besides system and scenario analysis no other explicit integrative method (as for instance geographical or other sorts of information systems, planning techniques or indicator systems) was used within our sample. Table 3 also shows that a considerable part of our sample did not rely on explicit methods of knowledge integration, but used more informal ways instead (common sense,

discussions among involved persons, pursuing a common goal or product).

All projects link heterogeneous stocks of knowledge by discussing the relevance of research results with respect to certain hypotheses or by relating contributions to the intended output or product of the project. In project no. 14, for instance, the anxiety about a specific environmental change was translated into a set of twelve hypotheses, and the results of more than 70 research projects were assessed with respect to their contributions to this set of hypotheses. Project no. 12, on the other hand, intended to establish know-how and an institutional setting for an eco-label. Therefore, this intended product served as key for the integration of many research projects and negotiations among stakeholders. In a similar way, the intention to develop an industrial production chain that uses only raw and intermediary products from organic origin served as frame of reference for integrating a series of subsequent research projects and the many steps within them (no 6). In other projects, visions of environmental or regional development (no. 1 and 4), of innovations in the education sector (no. 2), of alternative infrastructures (no. 10 and 13), or only a set of thematically related anxieties served as an integrative focus in a less rigid way.

Within such integrative frameworks, pieces of knowledge were often linked to others like bricks as parts of a larger construction. Results from earlier project phases are needed as precondition (information or framework condition) for subsequent steps (i.e. data on exposures to an air pollutant as precondition to determine an emission threshold). Such a 'brick system' was often applied for the investigation of causal chains. Besides this composition of elements to a larger entity, most projects also involved some sort of synthesis that was not guided by explicit methods, such as forming or summarizing a narrative or using unifying metaphors.

Our investigation reveals manifold forms of knowledge integration, most of which are neither recognized as such, nor carried out in a methodologically rigorous manner. This must not be understood as a critique of the projects. In all cases, however, the 'problem' (or the intention, the vision, the theme, etc.) of TDR projects and programs turned out to be the key to knowledge integration. This fact underscores the significance of 'problem-orientation' as the central feature of TDR.

Participation

In our sample, participation means that some extra-scientific partners are at least formally involved in the project or program, which is more than just being interviewed or making data available (e.g. from the administration) to the scientists. To various degrees, participation comprises co-responsibility and steering functions with respect to the project as a whole. However, our focus is on the functions that participation fulfils in knowledge production

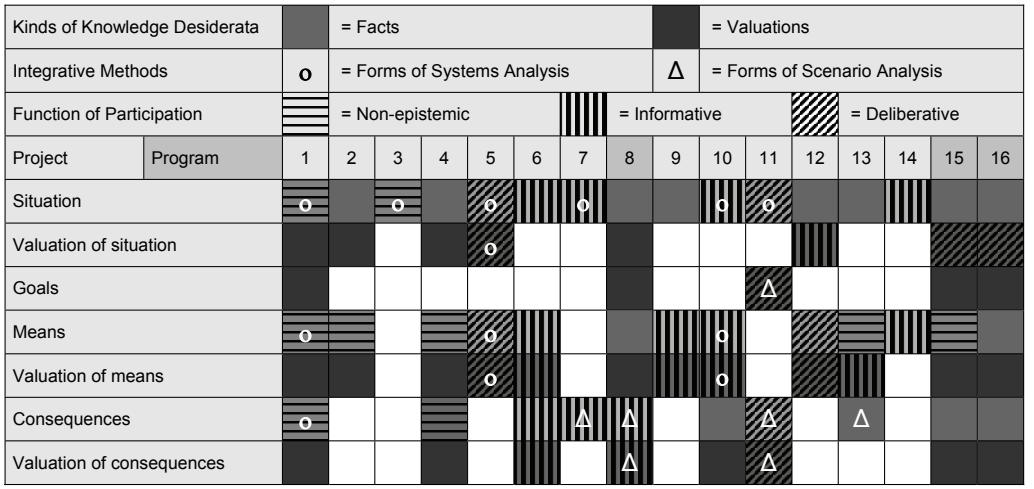
According to our understanding, 'life-world problems' represent barriers for actions. This may be due to lack of knowledge, but also due to missing means, conflicting interests or incommensurable value systems of the involved actors. These latter kinds of problems cannot be solved by only providing additional information. Rather, solutions will demand that actors find a compromise, change their minds or learn to see the situation in a different light. Negotiation, deliberation and mutual learning are thus procedures that may lead to solutions. Reflecting on his own experiences from participa-

tive research, Truffer (2002: 37) distinguishes the roles of researcher, mediator and promoter. Mediating diverging perspectives and interests, as well as promoting a political or an economical project transcends the traditional tasks of scientists. In some of our projects, the scientists were in fact initiating, organizing, leading and analyzing conflict-related deliberative processes. Conflict mediation and scientific investigation then fuse, and ideally, both are carried out in a rational way by subjecting the process to specific management and research methods. Accordingly, participation fulfils various functions. If scientists just compile and integrate information gained from their extra-scientific partners, we will speak of an *informative* function of participation. But as soon as cognitive processes related to knowledge desiderata are embedded within discursive or argumentative project settings—e.g. negotiations concerning collective decisions—we will speak of a *deliberative* function of participation. Within participatory research, scientists should take into account that the form of their investigation, e.g. systems or scenario analysis, might interfere with the progress and the outcome of those deliberations. Consequently, certain knowledge desiderata will not refer to a reality given in advance to the research process, but to an intended, yet in detail unknown result of a deliberative process. Besides these two epistemic functions of participation we also encounter *non-epistemic* functions. Our sample reveals cases in which cooperation with extra-scientific actors does not serve immediately to generate information with respect to some knowledge desiderata, but fulfils other purposes of the project, like decision-making, providing legitimacy or establishing contacts.

We find all three types of participation in our empirical set (see Table 4). *Non-epistemic participation* occurs fairly often in our sample. Typical examples of non-epistemic participation are joint decisions about actions or measures to be taken (no. 1, 2, 4, 13 and 15), cooperation with extra-scientific partners in order to get support for measurement systems (no. 1 and 3) or to be allowed to carry out activities on private property (no. 1 and 13). Not all non-epistemic functions can be shown in our table, for in many cases they are a precondition of informative or even deliberative participation and consequently subsumed under these. Furthermore, particularly in programs and larger projects, extra-scientific partners participate in steering committees and other supervising bodies. Since these forms of participation have no determined relation to particular knowledge desiderata, they are not shown in Table 4. In addition, we have to keep in mind that programs are only analyzed on the program level, which means that we may encounter various forms of participation within their individual projects. However, surveys, interviews, work with focus groups and other classical forms of social scientific investigations are not regarded as participative research.

The *informative function of participation* consists mainly in providing access to data or to know-how which is commonly not available to scientists, such as internal data of enterprises (no. 6, 7 and 10) or administrations (no. 14), the experience of politicians (no. 9), or of local experts like farmers or foresters (in projects 5 and 11, hidden behind the deliberative function in Table 4). In some cases not only the factual knowledge of affected laypersons, but also their values and attitudes are investigated through participative forms of research (no. 5, 8 and 13). Again, some of these cases are

Table 4: Knowledge desiderata, methods of knowledge integration and forms of participation in transdisciplinary projects and programs.



not shown in Table 4, because they are part of participations with deliberative functions. Informative participation is in many cases a two-way ticket. On the one hand it secures access to non-scientific stocks of knowledge; on the other hand it allows the extra-scientific partners to keep an eye on the adequate and legitimate use of their own knowledge by the scientists. This is of special importance if the data are in need of interpretation. Eventually, in Table 4, informative cooperation often also encompasses non-epistemic cooperation.

Deliberative forms of participation in research may include non-epistemic, as well as informative elements. Deliberative participation stretches into the process of knowledge production itself. Scientists may then indeed play all the roles on Truffer's list. The deliberative production of knowledge sets out from the initial knowledge of the collaborating non-scientific and scientific partners. The research goal may be to achieve a rational and fair step ahead in a development process (no. 11 and 12), to balance interests (no. 5 and 12) or even to settle a conflict (no. 5). Typically, all the extra-scientific partners are involved in the context of the life-world problem, either as stakeholders (industry, NGOs, property owners, affected population), political representatives, officials from the administration, or as experts.

Research settings that include deliberative forms of cooperation may create a virtual situation of decision-making, which relieves the actors from the pressures and consequences attached to 'real-life' decision-making. This was for instance the case in project no. 11, which dealt with options for a sustainable regional development. Although real actors are involved, the research setting allows rather unrestricted discussions because they can treat issues hypothetically without being tied to strategic or instrumental communication. On the other hand, project no. 12 established an institutional context that permitted real negotiations, decision-making and setting up of contracts among stakeholders, which would not have happened otherwise. Project no. 5 represents some intermediate position, by initiating a

process of negotiations which led to decisions made outside the project in established political institutions. Within programs no. 15 and 16, the function of deliberative participation of authorities and stakeholders was to identify research topics and priorities, as well as to discuss the structure of the program and the call for research proposals. Participation was therefore confined to very specific phases of the programs.

From the perspective of stakeholders and society, the benefit of involving scientists in deliberative processes is to enhance the level of information, to provide a corrective against factually false positions, to create a climate of rational discussion, and to create either a space of hypothetical decision-making (no. 11) or to establish even the necessary institutional preconditions for authentic communication (no. 12). Deliberative participation thus typically unites mutual information processes, learning, negotiations and systematic investigations with respect to a particular case.

We have observed participation with epistemic functions stretching across almost all of the knowledge desiderata of our conceptual scheme. Compared with other forms of participation, however, deliberative forms seem to be more often applied for evaluative issues. In our sample, the projects that apply explicit methods of knowledge integration also apply them in a participative way.

Summary of empirical results

Our sample is too small and too heterogeneous to derive quantitative conclusions or generalizations. Yet, our empirical analysis reveals new and relevant information concerning the relation between epistemic ends (knowledge desiderata) and research means (forms of knowledge integration and participation) in transdisciplinary research settings. We would like to point out the following results:

1. The projects deal with problems of very different sorts, and, accordingly, they show quite different profiles of knowledge desiderata. Although almost all projects produce more than classic explanatory knowledge, it is remarkable that only few projects really investigate 'knowledge of objectives', which is one of the reasons normally given for TDR.
2. Very often participation does not serve knowledge production directly, but has the function of establishing favourable institutional or technical framework conditions for research. *Formal* transdisciplinarity does not always coincide with *epistemic* transdisciplinarity – a distinction poorly represented in the debate so far.
3. In correspondence with their specific problem-orientation the methods employed range from rather classic research approaches to the application of sophisticated integrative methods in combination with deliberative participation. It is again noteworthy that the claimed new mode of knowledge production is in many cases done in quite a traditional way.
4. A few projects in the sample nurture the assumption that combinations of methods for knowledge integration with deliberative participation might be particularly productive instruments for dealing with value-sensitive problems, e.g. development issues and conflicts of interests.

Discussion

Our empirical results indicate a certain congruency between conflict-related problems and an emphasis on evalu-

ative knowledge desiderata, as well as deliberative forms of participation. Yet, the heterogeneity of the empirical cases reveals that there is no point in reducing TDR or problem-oriented research to a particular well-defined research setting. A specific TDR project may, for example, exemplify non-epistemic, informative or deliberative modes of participation. Some TDR researcher will rely on qualitative scenario modelling as an explicit method of knowledge integration (see e.g. Scholz and Titje, 2002), while others use no specific integrative tools at all. As all the projects and programs in our sample fulfil the formal criteria for transdisciplinarity, our empirical results strongly suggest that there is no single blueprint for TDR from an epistemological or methodological perspective. Seen from this point of view, TDR does not appear as a distinctively new mode of knowledge production. Transdisciplinary research projects that seem formally to call for interdisciplinarity and participation employ and combine different methods and collaborations with respect to their cases, contexts and objectives. Nevertheless, in a rather general way one could understand problem-oriented research as a new mode of knowledge production, particularly in cases when participative research interferes directly in decision making and political processes.

In any case, one has to pay strong attention to the methodological aspects of doing such participatory problem-oriented kind of science. This is the reason why we take it to be of great importance to disentangle the notion of transdisciplinarity and to have a closer look at the many faces of such scientific practice. In the following, drawing from the previous section, we will break down this issue into a discussion of sets of epistemic ends and related research means, with a focus on the function of integrative methods and participative research forms.

Problem-orientation and integrative research methods

In order to assess the potential performance of integrative methods, the meaning of 'knowledge integration' should be more closely scrutinized. There are at least three types of integration as far as its objects are concerned. The first kind is elementary for the building of any stock of knowledge, namely the coherent and systematic ordering of information regarding a theme or topic. Such categorization is needed as a first stage in theory building or inferring law-like generalization, but also any successful learning, drawing of conclusions and planning in everyday life rests on such kind of knowledge integration. We might call this the *thematic integration* of knowledge.

If the 'theme' was the realization of an action or a product, then the thematic knowledge components would be additionally related to the elements of an action or the phases of a production process, which include goals and related values. Knowledge production would be organized in a way compatible to the matrix of knowledge desiderata (see Table 1), and we might speak of *problem- or product-oriented integration.* All socially competent actors display at least an implicit understanding of the internal structural components of actions (situation, ends, means and consequence). However, an explicit understanding of this structure is a precondition for dealing with problems in a rational or methodical way, as for instance in economical, political or ethical analyses or in technology assessment.

A third kind of knowledge integration refers to the knowledge of various kinds

of actors, like laypersons and experts, and we might call it *social integration*. This type of integration seems especially challenging for scientists since it involves types of knowledge that have quite different qualities of validity, such as 'local' (or experiential) knowledge vs. 'generalized' (or scientific) knowledge, factual and evaluative knowledge, or individual interests of affected persons vs. ethical maxims. In general, systematically structured argumentation lends this kind of knowledge integration a certain degree of rational control and enables reproduction.

Although we find all three types of knowledge integration in our sample, only a few projects rely on specific integrative methods. Probably due to the fact that competent actors employ various forms of knowledge integration in their everyday routines, the need to follow explicit integrative methods is not strongly felt by practitioners of TDR. Problem-oriented research does not appear to require specific methods of knowledge integration. We must keep in mind, however, that the use of integrative methods may contribute considerably to the epistemic performance of TDR. As we have seen, particularly the combination of systems and scenario analysis is used as a method to rationalize the analysis of a problematic situation, to clarify goals and to develop strategies that take consequences into account. Since one can apply these formal instruments to many types of empirical information, they allow for thematic, problem-oriented and social integrations across all fields of our matrix of knowledge desiderata and for any thematic context.

Problem-orientation and participative research forms

What most advocates of TDR possibly have in their minds as a paradigm case are projects that apply methods of knowledge integration and deliberative participation in order to solve a problem through negotiations among stakeholders. Yet, one may produce knowledge for action by the means of non-epistemic participation (projects 1, 2, 3 and 4), informative participation (projects 6, 7, 8, etc.) or deliberative participation. Some texts promote TDR as if it were *demanded* by complex societal problems (e.g. Scheringer et al., 2005). However, neither our empirical findings nor our theoretical reflections support the view that problem-oriented research *necessarily* needs one of the two forms of epistemic participation. It is not even self-evident whether participation per se is really needed to elaborate knowledge for action. Local, specific, contextualized knowledge of extra-scientific actors may of course complement general scientific knowledge and contribute considerably to research endeavours. Moreover, the interests and perspectives of the involved actors are often constitutive for the problem of the case. However, standard non-participative empirical methods in social sciences and economics (surveys, interviews, experiments, observation of decisions, etc.) may also be well suited to deal with 'local' or 'situated' knowledge and with many kinds of evaluative issues.

Although participative research may often be adequate and fertile, participation as such cannot serve as the distinctive feature of problem-oriented research. As we have elaborated above, 'problem-orientation' represents a set of cognitive ends. Participation, however, represents a class of research forms. All our projects were 'problem-oriented', but only in some participation had an epistemic function. We even find problem-oriented research without any participation at all. In the end, none of the

cognitive ends of problem-oriented research require participative forms of research per se.

Conclusions

We recall the exemplary characterization of TDR by Häberli et al. (2001: 7): TDR involves cooperation among different parts of society and academia in order to address complex, tangible real-world problems. Deliberative participation in problem-oriented research may thus capture what promoters of TDR or Mode 2 knowledge production paradigmatically have in mind. However, neither forms of epistemic participation nor methodical knowledge integration are a standard in projects that fulfil the formal criteria of TDR research. Participation may even serve many other objectives than knowledge production in the strict sense. An interesting finding in this context is that deliberative participation may subject negotiations of stakeholders to scientific standards of rationality and thereby affect the result of the process.

Solving problems that are constituted by lack of knowledge among the involved actors about their different positions, preferences, interpretations and attitudes may indeed require that these actors mutually produce this decision-relevant knowledge in processes of deliberation and negotiation. Although they do not necessarily need scientific support to achieve a solution, science may contribute in a triple way, namely by informing the actors, by rationalizing the process and by taking the results as data for further scientific analysis. Integrating *deliberative knowledge production* into a participative research setting may be an adequate way to achieve good results.[1] Insofar as deliberation and investigation, politics and science overlap or merge to some degree, such approaches indeed exceed the limits of classic empirical methods of social research, since the latter are based upon the assumption of independent objects of research and designed to use non-intervening methods. Rather than calling for a particular set of research forms, problem-oriented research may on the contrary demand case-dependant methodological designs. We also proposed that the analytical structure of informed actions or decisions provides a key to identify types of knowledge desiderata. This conceptual background enables scientists to define forms of empirical investigations and knowledge integration appropriate to their epistemic objectives in question. Hence, this concept may serve as a fertile methodological foundation of problem-oriented research.

Our findings permit us to take TDR as a collection of rather heterogeneous sets of relations between epistemic ends and epistemic means. We thus reject the implicit 'unity thesis' of the common TDR discourse and regard it as problematic to speak of transdisciplinarity or of Mode 2 knowledge production as if they constituted a unified mode of doing research. Such semantics may be acceptable in order to promote some science policies, but it is not tenable from the epistemological and methodological points of view. A methodological clarification of TDR would instead require disentangling the concept in order to assess relations between certain sorts of knowledge claims on the one hand and kinds of research forms (such as knowledge integration and participation) on the other hand. Our exemplary analysis provides, we suggest, at least some preliminary conceptual tools for establishing such methodological means-end relations in respect of TDR.

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Notes

1 Burger (2005) presents additional arguments for genuine epistemic participation, focusing also on functional differences between democracy and its legitimacy on the one hand and science and its legitimacy on the other hand. For Wiek (2007), mediated negotiation at the transdisciplinary interface between scientists and local experts may even lead to a new type of multi-layered peer review of expertise.

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Wolfgang Zierhofer and Paul Burger
Program Sustainability Research,
Department for Social
Sciences and Philosophy
University of Basel, Switzerland
wolfgang.zierhofer@unibas.ch
paul.burger@unibas.ch