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COGNITIVE INTEGRATION IN TRANSDISCIPLINARY SCIENCE

Knowledge as a Key Notion

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***Abstract*:** We argue for an understanding of *transdisciplinary modes of scientific knowledge production* that rests on assumptions regarding the specific tasks and challenges for a "problem-solving" or "action-oriented" science. [1] A comprehensive model of analytical tasks in scientific knowledge production is put forward comprising: (1) the production of systemic knowledge; (2) the assessment of systemic properties; (3) the analysis of systems of goals, goods, and values; and (4) the assessment of actions. It is part of our understanding of transdisciplinarity that, although classical disciplinary knowledge production usually addresses only one of these tasks at a time, transdisciplinary knowledge production usually aims at addressing several or all of them simultaneously. It is this ambition that generates the *needs for integrative processes* in transdisciplinary projects. After introducing a distinction between *cognitive* and *social* integration, we argue for our claim that at least *cognitive* integrational tasks, and the objects of resulting synthesis in research and higher education, can be mapped onto a matrix of these analytical tasks. Further, we argue that such a mapping allows for more targeted and more specific formulations of the integrational tasks. On the basis of a substantial concept of knowledge, we then lay out and discuss *three areas of cognitive integrative processes in transdisciplinary science*: (1) the four domains of scientific analysis, (2) disciplinary divisions of labor within domains of analysis, and (3) heterogeneous (scientific as well as non-scientific) expertise.

The Cognitive Goals and the Consequent Tasks of Transdisciplinary Research

The *International Transdisciplinarity 2000 Conference* has seen a shift regarding the understanding of "transdisciplinarity."[2] Until then, notions of inter-, multi-, cross-, or transdisciplinarity often seem to have all been used differently by different authors;[3] after the Zurich Conference, at least one aspect of "new" modes of scientific knowledge production has come to be acknowledged more widely. This is the "participatory," "problem-solving," or "action-oriented" aspect of science, and it is motivated by *extra-scientific*, *societal* challenges for research (Klein and Grossenbacher-Mansuy, et al. 2001). This conceptual shift has been influenced by the concepts of "socially robust knowledge" and "mode 2 knowledge production" introduced by Gibbons and Nowotny, et al. (1994) and further developed by Nowotny and Scott, et al. (2001). We start with an attempt to clarify this modified understanding of transdisciplinarity.

We characterize "transdisciplinary science" as (1) cognitive and social cooperation across disciplinary boundaries, (2) an intention towards the direct application of scientific knowledge in both *political decision-making* and *societal problem-solving*, and (3) the participation of non-scientific stakeholders within research processes. Whereas we understand "interdisciplinarity" as referring mainly to facts of *intra-scientific* cooperation as expressed in (1) above, "transdisciplinarity" additionally aims at capturing the societal "action-orientation" of science and the participation of non-scientific stakeholders in research (Burger & Kamber 2002). Although the two concepts are logically independent of each other, we believe that transdisciplinary research will typically be interdisciplinarily organized, but not necessarily *vice versa*. Since we are not interested in an *explicit definition* of "transdisciplinarity," this characterization is simply designed to give an indication of the constraints regarding the kind of science that will be the subject matter below and whose instances we see as representing certain "family resemblances."[4]

Any demand for transdisciplinary science will have to be motivated by beliefs about the *specific potentials* of "new modes" of research as compared to the potential of disciplinary research. Furthermore, such potential is to be seen as somehow *relevant* regarding genuine challenges for contemporary science. In an attempt to summarize the many heterogeneous claims represented in the literature on transdisciplinarity, we suggest that these challenges are the problems of (1) the relationship between science, political decision-making, and research-based societal action; (2) generic knowledge; (3) specialization in science; (4) the integration of non-scientific expertise and problem-views in research; and (5) the fact-value dichotomy. The key characteristics of transdisciplinarity stated above (cooperative knowledge production, action-orientation, and the participation of non-scientific stakeholders) are thought to represent the general means for tackling challenges of these kinds.

Imagine a concrete case, for example the concerns for biodiversity and a functional ecosphere in an urban, highly industrialized region. A publicly financed environmental institute launches a project aiming at an integrated system of biotopes within that region and succeeds in raising the resources necessary from a regional development fund. The project starts from the assumptions that humans need a functional ecosphere for their health, recreational, and aesthetic needs, not only in the distant wilderness, but also in the immediate urban and peri-urban environment. Further, this ecosphere is seen as having important functions as a sink and provides living spaces for diverse species potentially endangered by urban development. Despite these attractive goals, there are serious difficulties regarding the implementation of the planned project. First, there is the official claim of a possible threat for the regional water supply. It is suspected that the renaturalization of riverbeds will lead to an increase in contamination of groundwater. Furthermore, there are divergent and partly conflicting interests regarding zoning, and there is a public controversy about the economic appropriateness of the project in a time of decreased public spending. In the course of the controversy, advocates and opponents of the project agree to involve researchers from the regional university to carry out an independent study in order for stakeholders to generate a common and science-based foundation for political decision-making regarding funding for the project. Below, we are going to argue for our contention that contemporary academic science may be ill-equipped to deal with specific kinds of challenges involved in cases such as the above.[5]

1. Science for Political Decision-Making and Societal Action

Much of contemporary science produces knowledge within a context of intra-scientific relevance criteria (e.g., the connection to existing knowledge, explanatory or predictive potential, contributions to theory development).[6] If such criteria are interpreted normatively, they represent part of the foundations for the well-known claim for freedom of research. According to these criteria, scientists should choose their subject matter independently of societal concerns. Moreover, the practical problems involved in our case *as such* are likely not of any *direct* scientific relevance. Researchers will need to break down the cluster of problems into small problem chunks that can generate research questions, and they will be doing this in accordance with their own specific disciplinary views on the practical problems at hand.[7] Through this process, the original problems will usually be transformed, sometimes dramatically, according to the interests of the researchers involved. Consequently, the transformed problems may no longer be viewed as relevant for the issues perceived by non-scientific stakeholders. Put differently, any claim laid on science regarding the concrete political, social, or economic significance of research constitutes an institutional challenge to scientific knowledge production since intra- and extra-scientific imperatives regarding problem choice differ. This can be generalized in the following way: Legitimate claims about freedom of research need to be weighed sensibly with the equally legitimate claims of society regarding the extra-scientific significance of research carried out, moral, social, or economic reservations about the subject matters or the methods of science, and the assessment of potential harm implicated by new knowledge and the ways of reducing such risks to society. However, the contemporary system of rewards and funding in research is ill-equipped for such weighing to properly (and not only informally) take place.

2. The Problem of Generic vs. "Local" Knowledge

Whereas the societal concerns discussed in the previous section represent an institutional challenge for science, the problem of *local* knowledge concerns science's intrinsic properties. Scientific knowledge production is oriented towards *the most general and comprehensive knowledge available relative to a specific subject matter*. Predictions regarding its subject matter are based on knowledge claims about causal relationships as well as nomical (including probabilistic) and conceptual relations that are assumed to apply in the total domain at hand. Our example has, however, the character of a *case study* where one of the main challenges consists in the *adequate* formulation of research questions derived from the complex cluster of social, ecological, and economical problems given, that is, a formulation of research questions that will actually allow for the production of *case-relevant* knowledge. As a consequence, academic researchers may, on the one hand, hesitate to engage in such projects because they see too little potential regarding their involvement as researchers in tackling it *as it stands*. On the other hand, their own knowledge base may turn out to be inadequate for carrying out such a study, if its application is, in principle, restricted to much more artificial contexts. Such discrepancy is notoriously underestimated in contexts of scientific expertise for political decision-making (Wynne 1989; Renn 1995; Weingart 2001; Collins & Evans 2002)–hence the claim for knowledge production within, or directly connected to, the according local context (Gibbons et al. 1994). The challenge for science consists in the fact that such claims are often unclear about the exact nature of "local knowledge" or "expertise" and its amenability to research. Furthermore, in our experience it is a common occurrence in transdisciplinary projects that the actual, concrete results of research carried out do not match the extra-scientific problem-solving needs because the latter *presuppose research regarding the implementation of the very results of such projects*. We call this phenomenon the "application gap."

3. The Problem of Specialization in Science

The highly successful process of the division of labor in science has had unwanted and disagreeable side effects. The problem of specialization that concerns us here is that of *social and cognitive side effects within the sciences*. Not only are scientists that are trained in ever-more specialized fields increasingly prone to some degree of ignorance about the wider significance of their work, but they may also be ignorant of the potentially productive connections to other fields of inquiry.[8] They may also lack principled ways to deal with complex extra-scientific problems, especially if the latter involve political decision-making and societal problem-solving. To our minds, this is not at all a problem of "ethics," that is, the presumed lack of proper moral attitudes of researchers towards such problems. On the contrary, strong attitudes of this sort may contribute to an unintended and further veiling of the actual social and cognitive obstacles regarding the commitment of researchers to extra-scientific problem-solving.[9] The extra-scientific stakeholders involved in our example above are neither interested in a collection of *ad hoc* suggestions labeled "expertise," nor in research results that are of the highest quality but too abstract to be applied in their complex case. More generally, stakeholders involved in political decision-making or societal problem-solving want competent researchers capable of genuine intra- and extra-scientific cooperation and, of course, a genuine concern for practical and research-based problem-solving. This combination of competences regarding scientific knowledge production is neither covered by orthodox academic curricula, nor by contemporary patterns of incentives for researchers, or the paradigms of research organization.

4. The Integration of Extra-Scientific Expertise and Problem-Views in Research

Our example illustrates that, on the one hand, local actors *qua* stakeholders represent *special interests,* but they must not be reduced to such interests. The call for participation in transdisciplinary research is precisely motivated by the intuitively appealing assumption that “local” stakeholders also represent *expertise* valuable for problem-solving. But, clearly, researchers cannot take claims of local expertise at face value if they seriously consider the integration of such expertise into research processes. The *localization, assessment, and integration of local expertise* are thus crucial for the reliability, or “robustness,” of the resulting scenarios. Again, the integration of extra-scientific expertise may deeply influence the formulation of research questions, the selection of disciplines, the organization of research, iterative processes in knowledge production, and project costs. Furthermore, stakeholders involved in “cases” may not only know much about specific facts of the matter at hand, but they may also know about “what” to do and “how” to do it. Consequently, a serious commitment to participation raises important challenges for almost all practical and theoretical aspects of transdisciplinary research if such kinds of “social knowledge” are to be relevant for *research*.[10]

5. The Problem of the Fact-Value Dichotomy

The fact-value distinction is one of the more notorious subject matters within philosophy of science and science studies. There are at least two interlinked aspects. The first, and somewhat less controversial, is that there is a logico-semantical difference between factual statements and value judgments. The second and highly controversial part focuses on whether or not research is exclusively concerned with fact and whether or not facts are dependent on values.[11] Even if one grants the possibility of objective knowledge production, it is obvious that non-epistemic values will enter research processes in certain ways in cases such as the one above. For example, researchers will need to account for the relative function of ecological, economical, or social goals involved in the case descriptions at hand, and they will need to come up with means to link such assessments to scientific knowledge about, say indicators of the dysfunctions of peri-urban ecosystems. The tentative, but productive, demarcation between facts and values will thus play a crucial role in contributions to cases such as ours (Burger 2003a). However, goals, goods, and values can *themselves* be the subject matters of research, although this is often not acknowledged in the (e.g., environmental) sciences. Furthermore, researchers may often be unaware of the tacit values underlying their commitment to specific issues in their research.

These challenges may now preliminarily be related to our three characteristics of transdisciplinary science. For example, cognitive and social cooperation across disciplinary boundaries is thought to contribute to a tackling of the challenges of specialization and the fact-value dichotomy. The explicit orientation of research towards political decision-making and societal problem-solving is obviously directed to the according challenge, but it is also related to the problems of generic versus local knowledge and the integration of extra-scientific expertise and problem-views in research. Furthermore, the characteristic of participation is thought to contribute positively to the critical relationship between generic and local knowledge and to the integration of non-scientific expertise and problem views.

Societal Problems and the Role of Knowledge in Transdisciplinary Research

In order for us to ground our discussion of such potentials of transdisciplinary science we need to introduce several basic notions first. We view transdisciplinary research as "action-oriented" insofar as it attempts to contribute to political decision-making and societal problem-solving by meeting the above challenges in the production of knowledge. But what can reasonably be expected from *research* regarding political decision-making and societal problem-solving? Although we cannot attempt to answer this disputed and difficult question conclusively here, we will try to contribute to its clearer formulation by drawing the boundaries of a reasonable and legitimate involvement of science in societal problem-solving.[12] Our subsequent discussion is based on presuppositions regarding the generic "product" of *research*, that is, *knowledge claims that are justifiable under systematic methodological restrictions*.

The Properties of Scientific Knowledge

Colloquially speaking, science "produces" several kinds of things. It may be viewed as providing society with the technological means for controlling the natural and the cultural world, or as producing elitism and power structures that contribute to science's own internal interests or perpetuate the political status quo. Science as a social institution, however, can reasonably and legitimately be expected to produce *reliable knowledge that is significant for political and societal concerns*.[13] Knowledge is most reliable if it has been produced under systematic methodological restrictions. Indeed, the way transdisciplinary research is conceptualized here is to ensure that *scientific problem choice* as well as *knowledge production* are directed towards the societal significance of the knowledge thus produced.

"Scientific knowledge" is commonly identified with *propositional* knowledge, that is, knowledge that is represented in propositions such as '*a* is *F*' or '*x* stands in the nomical (or statistical, causal, functional, conceptual) relation *R* to *y*' and the like. This notion of knowledge has been developed in epistemology where it is explicitly defined as *justified (or warranted or reliable), true belief*. Regarding our concerns for cognitive integration, it is the notion of justification that represents the core element of the concept of knowledge thus defined. That is why we use the expression "scientific knowledge production" (or "research") to refer to knowledge production that is systematically restricted by *methodological*, that is, justification-related, standards. Furthermore, all scientific knowledge claims refer explicitly to highly specific subject matters, and they thus presuppose some kind of *ontological* commitment or other.[14] Scientific specialties can thus basically be discriminated by, among other things, the specific characteristics of their methodological and ontological patterns. Since all knowledge claims resulting from disciplinary as well as from transdisciplinary research will have to satisfy such restrictions, we suggest that *cognitive integration in research* is basically about the integration of heterogeneous claims of scientific knowledge–and thus about the integration of heterogeneous methodological and ontological patterns.

Apart from the facts that there are other notions of "knowledge" being discussed in epistemology[15] and at use in other fields,[16] we believe that the notion of propositional knowledge is well suited for the analysis of cognitive integrational tasks in transdisciplinary modes of knowledge production. It is one of the few explicitly defined notions of knowledge, and there exists a distinctive consensus in epistemology and the philosophy of science that scientific knowledge is to be identified with propositional knowledge thus defined. Nevertheless, it cannot cover all our analytical concerns regarding transdisciplinary research.

"Transdisciplinary Problems"

We view transdisciplinary problems as typically representing problems in *both* the sense of the need for *knowledge* as well as of divergences between the *perceived disagreeability* of current states of affairs and *desired conditions* regarding the latter. Furthermore, societal issues such as those in our example can be regarded as "ill-defined" problems because, initially, contributions to their solution will involve *knowledge about systemic transformation processes,* where the initial as well as the target states are mostly unknown and so are the elements and determinants of the transformational processes.[17] But since not all ill-defined problems call for integration of research tasks in our sense, we want to call the kinds of subject matter typically involved in transdisciplinary research "complex," in the colloquial sense of being irreducible to only a few *kinds* of variables or causes. Finally, cases such as our example not only incorporate needs for knowledge and action but also divergent and typically conflicting *claims regarding actual and desired states of affairs as well as assumptions about the adequate means for goal-directed action*. It follows that transdisciplinary research commits itself to two basic tasks: the entanglement of complex, ill-defined problems and the production of reliable, action-oriented knowledge.

Cognitive Goals of Transdisciplinary Research

The basic cognitive goals of transdisciplinary (as discriminated from disciplinary) research can now be defined as producing knowledge under systematic methodological restrictions that will: (1) describe the complex subject matters of transdisciplinary problems more comprehensively, (2) explain their properties and the nomic relationships between their elements more reliably, and (3) contribute to more adequate predictions and scenarios regarding their behavior. To our minds, (1) to (3) represent criteria regarding any useful notion of transdisciplinary *research*.[18] But claims about the comprehensiveness of descriptions, the reliability of explanations, and the adequacy of predictions are in need of further explication.

The generic goals for transdisciplinary research above are to be reached through scientific knowledge production in its narrow sense. The motivations and the concrete need for *cognitive integration*, however, arise within these narrow contexts of transdisciplinary research as well as within a wider context of any transdisciplinary project. In the next sections, we will discuss one area of integration in research understood narrowly, the domains of scientific analysis.

Four Domains of Scientific Analysis

Our notion of domains of scientific analysis has its origin in programmatic policy statements regarding problem-solving science in Switzerland. In a report prepared for the Conference of the Swiss Scientific Academies (1997), in order for the latter to develop policy elements regarding the funding of sustainability research, three basic areas of scientific analysis are suggested. For research to sensibly address sustainability challenges, it is necessary but insufficient to produce "systemic" knowledge (*Systemwissen*), that is, factual knowledge about natural, social, and conceptual systems. The report states that such research also needs to address "transformational" knowledge (*Transformationswissen*) and "goal-related" knowledge (*Zielwissen*).[19] The idea behind these notions is straightforward.

In order for researchers, society, and policy-makers to base decision-making regarding sustainability on adequate knowledge, it will not suffice to know the structures and properties of systems. We also need to factually evaluate different kinds of impacts on such system (e.g., "threats" or "risks") and their relationships to our intrinsic interests, how we should proceed in order to achieve change or development favorable to these interests, or what the deeper foundations of our interest are in the first place. The analogy to a general concept of *social action* is obvious: any social action can be assessed regarding its goal, the means for its attainment, as well as its conformity to social norms and cultural values.[20] Since the notions of *Systemwissen*, *Transformationswissen*, and *Zielwissen* are difficult to discriminate epistemologically or methodologically we propose instead to discriminate four *domains of analysis* that will be able to analytically capture the intentions behind these notions (see Fig. 1).

Domain 1: Properties, State Descriptions, and Explanations

Much of the sciences have traditionally been concerned with analysis and description of the properties, states, and behavior of its subject matter. Certain traditions and specialties, especially within the empirical sciences, have laid more weight on quantitative and explanatory ventures. Others, most prominently among them certain quarters in the social sciences and most of the humanities, have included the paradigm of a qualitative *Verstehen* (understanding) in their tasks. To our minds, these approaches all equally aspire to contribute to furthering knowledge, that is, of explanation and understanding of the natural world, as well as the domain of social, conscious, and conceptual entities and their histories, conditions, places, and doings in it. What science basically contributes within this domain is *factual* or *systemic knowledge*, that is *statements of presumed facts*, grounded in the best methods available to each specialty at the time being–and this goes for the natural as well as for the social sciences and the humanities.

In our introductory example, we are not simply facing the problem that the stakeholders (including researchers) may differ on behalf of their vested interests in the project, but also regarding the knowledge claims they raise about the structure and the properties of the cluster of systems in question. This is the field where empirical (natural and social) sciences are best established and where concurring claims of expertise may be decided with the least friction. It is systemic knowledge of this kind that enables decision-makers to *factually base predictions* in possible change scenarios.

Domain 2: Assessments of Properties and States

Many of the properties and states in our example are amenable to systematic and methodically guided *assessments*. The natural as well as the social sciences have traditionally been concerned with analytical tasks of this kind. To our minds, the humanities, too, have contributed in important ways to such assessments (e.g., by their critique and the historical or cultural contextualization of science, technology, modernization, and so on). But let us look closer at the characteristics of this analytical task. For example, the qualities of a specific ecosubsystem can be evaluated regarding its inherent diversity, its capability for adaptation given certain kinds of impacts, or its danger regarding its impacts on other systems. Further, in scenario-building based on systemic knowledge, influence factors restricting system behavior can be assessed regarding the different effects these factors have on the transformation or the end state of systemic processes. Nevertheless, the *deficiency* or *dysfunctionality* of a state of high joblessness, urban deterioration, or agricultural pollution or the like, cannot be determined by descriptions or explanations of the systemic states or processes alone. Rather, researchers concerned with assessments of this kind will look at the effects of such states or processes on, for example, the well-being of biological individuals, or the resilience of ecosystems or social systems. Once such effects are tentatively described and explained, they can only be valued with a tacit or explicit reference to goods or values. For example, joblessness is *undesirable because* of the deteriorating economical, social, and psychological effects it has on the individuals affected; high rates of joblessness are *undesirable because* of the effects they have on the economic, and maybe even political, stability of a society. The tacitly presupposed goods in these cases are the economical, psychological, and social well-being of individuals, or the economical and political stability of societies.

Within this second domain, there exist contingencies related to the domains of analysis below and above. Below, the potential uncertainty or incompleteness of factual, systemic knowledge translates into assessments in that predictions vary according to initial assumptions. Cost-benefit assertions regarding such predictions in the context of complex and practical problems are thus *inherently uncertain*. Above, regarding extra-scientific decision-making, such gaps of uncertainty or incompleteness will usually be bridged by tacit reference to political, economical, moral, or spiritual preferences. This need not be so, for such preferences can themselves be made explicit by stakeholders involved and thus become the subject matter of further analysis.

Domain 3: Assessments of Goals, Goods and Values

Sets of preferences presupposed by stakeholders in the systemic assessments discussed above can be methodically evaluated. From a methodological point of view, however, it is crucial to note that the assessment of goals, goods, or values will usually differ formally from the kinds described above in important ways. Goals such as the economic and social well-being of individuals are likely not intrinsic but instrumental values in any given scheme of values in a typical Western society. They may thus further be grounded in the presumably intrinsic value of personal integrity, thought of as the corporeal, mental, and emotional inviolability of a person. In our example, the value put on a "natural" environment because of its presumed role as a good for humans may collide with the value put on the economic prosperity of a region and its role for the social well-being of individuals in it. The assessment of instrumental goals, goods, or values will thus involve the axiological reconstruction of the internal consistency of, and dependency relations among, systems of instrumental and intrinsic goals and values. It can be of further use to reconstruct the historical and cultural genesis of certain schemes of goals and values in order to be able to relate such schemes to their historical and cultural diversity.

Such tasks have traditionally been the domain of ethics, but also of specialties in the social sciences and the humanities, such as political philosophy, critical theory, theology, historiography, economy, and many others. It is important to note that it is often typical of the results of such analysis that they cannot be assessed in the manner of, say, knowledge about the structures and properties of physico-chemical or biological systems, since their subject matter is in most cases purely conceptual. This raises the important issue of the epistemic status of knowledge in the (theoretical) social sciences and the humanities. Put differently, the tasks of "assessment" or "evaluation" of sets of goals, goods, or values, that is, the production of "goal-related knowledge," is formally different from the assessment of physical or biological systems. Depending on one's stance regarding fundamental doctrines in the philosophy of science, epistemology, and metaphysics, such tasks may not lead to definite results because the latter would presuppose some kind of external perspective of the evaluators that may not be available in principle.[21] Consequently, problems of risk and uncertainty inherent in the production of empirical knowledge may be complemented by problems of interpretation in parts of the social sciences and the humanities.

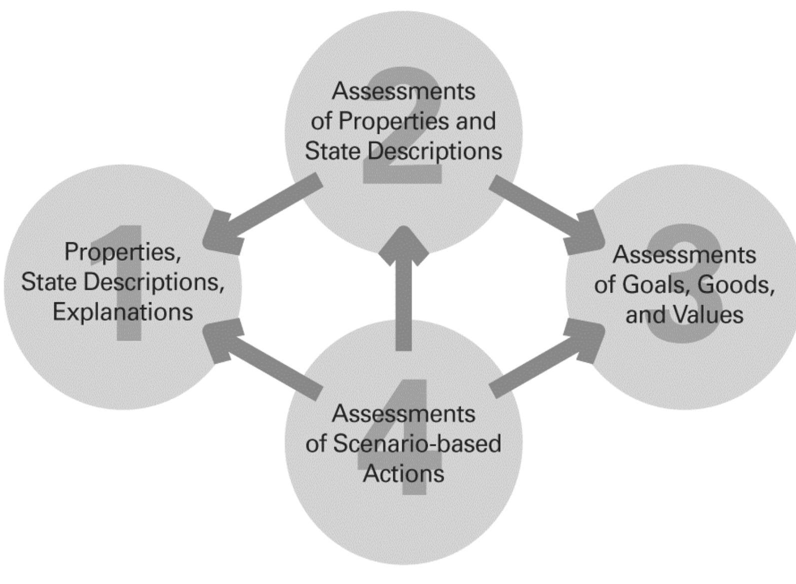

Figure 1. Analytical tasks in research for political decision-making and societal problem-solving. The arrows represent implications (see Burger 2003b for a concrete example of the application of this scheme).

Domain 4: Assessments of Actions Resulting from Research-Based Decision-Making

An integration of empirical and conceptual scientific ventures seems advisable once we set our eyes on the assessment of proposed solutions, action plans, and measures to be taken. These latter tasks represent the production of what has been called "transformational knowledge" above. The measures taken to attain certain goals, viewed as consistent with a given value scheme according to analysis within domain 3, can be assessed regarding their goal-attaining efficiency, their material and non-material cost, and their side-effects, be they desired or undesired. This task as a whole can obviously only be completed by an integration of empirical and conceptual scientific efforts since assessments within this domain of scientific analysis presupposes results in domains 1 to 3. The complexity of social issues as well as the special demands regarding knowledge for societal action makes stakeholder participation especially crucial in the domain of the production of transformational knowledge.

Integrative Tasks

The notion of domains of analysis in transdisciplinary research now allows for a preliminary formulation of the resulting integrative objectives. A crucial integrative task that has become visible is integration between domains, that is, the proper relating of research questions or results from within different domains of analysis. It is important to note that the meaning of "interdisciplinary" cognitive integration in research thus becomes twofold. It can refer to integrative tasks *between* domains and integrative tasks *within* a specific domain (between specialties) because there may be different specialties working within one single domain.

Although the two tasks above represent the cognitive integrative tasks in research, understood narrowly these are not the only cognitive integrative tasks with which researchers have to concern themselves. In transdisciplinary projects, there will be further tasks regarding the integration of non-scientific expertise (including the aspects of defining problems, knowing what to do, and how to do it), as well as the integration of research results towards their operationalization in political decision-making and societal action.

Goals of Integrative Tasks in Transdisciplinary Projects

We conceive of the general notion of "integration" as referring to a social or cognitive process of substantially relating different kinds of entities.

Accordingly, a *synthesis* is the outcome of such a process that will represent, itself, a *new kind* of entity. In research, this will usually be a set of propositions; in research and development, it will be a new product. However, since there may be incommensurable or incompatible entities, *synthesis* in any useful sense is not always possible everywhere. Moreover, there are processes of cognitive integration that may represent highly specific learning processes where learners acquire new beliefs about, for example, systemic boundaries relevant for the formulation of problems relevant for decision-making. So far, we have been concerned with the generic tasks (i.e., cognitive goals) of transdisciplinary research as we see them. In what follows, we will discuss *integrative tasks for researchers in transdisciplinary projects*. "Cognitive integration" can be used in a narrow sense where research tasks are concerned exclusively. In the following sections, we will use a wider notion of cognitive integration, including tasks that concern the integration of non-scientific expertise as well as the integration of research results regarding their application.

Cognitive Integration: Its Narrow and its Wider Sense

We have suggested viewing transdisciplinary research as a specific mode of knowledge production under systematic methodological restrictions. The languages of theories, hypotheses, research questions, knowledge claims, and so on, in any given area of inquiry are ontologically and methodologically specified languages. Consequently, the products of cognitive integration in research will have this form. Put differently, a suggested *goal* of a cognitive integrative process (its intended *synthesis*) will explicitly need to have the form of a hypothesis, research question, methodological proposition, theorem, or knowledge claim, and it will need to be *ontologically and methodologically specific*.

The cognitive integration of non-scientific expertise, as well as of research results regarding their application, may also have such propositional items as outcomes, but more often such integrative processes have the character of mutual learning processes and processes of understanding. For example, researchers learn how non-scientific expertise can contribute in important ways to the adequate formulation of research problems–if research is to contribute substantially to political decision-making and societal action. Or they learn how to properly involve extra-scientific stakeholders into such cognitive processes of mutual learning. Moreover, non-scientific stakeholders may learn a lot about an issue if they get involved with other stakeholders, among them researchers, whose perceptions and commitments regarding the issue differ in important ways from their own. Further, stakeholders may learn about important aspects of the relations between methodologically restricted knowledge production and political decision-making, and thus acquire knowledge that is crucial for future commitments to new transdisciplinary problems. Hence, such mutual-learning processes may contribute positively to the development of such skills in stakeholders in ways in which research and knowledge transfer alone cannot.

Considering the above, cognitive integration processes may easily be confounded with social integrative processes; the latter deserve a digression before we enter the discussion of cognitive integrative tasks as such.

Social Integration in Transdisciplinary Science

We speak of *social* integration if synthesis does not have a propositional but a social form, as, for example, in the cases of a project team, stakeholder groups, mutual-learning groups, consensual results of mediation sessions, and so on. We contend that social integration in transdisciplinary projects is strongly *instrumental* regarding the intrinsic cognitive goals of transdisciplinary science. But this is not meant to imply that cognitive integration is all that really matters in transdisciplinarity. We believe, instead, that what really matters is *cooperation*, and our three basic characteristics of transdisciplinary science introduced at the beginning of the article represent this basic contention.

As far as social integration is concerned we want to stress two aspects. First, scientific knowledge production, restricted as it may be by systematic methodological conditions regarding the evaluation of knowledge claims, is still a social activity. This should, however, not lead us to premature conclusions regarding the relationship between cognitive and social tasks in research. No matter what scientific propositions actually refer to, they are necessarily represented by *knowledge claims* within a specific setting of evaluation criteria regarding such claims. The *social* system of science is thus the context within which such claims are raised and evaluated. It is here where violations of methodological norms will occur–not simply because such norms may be ill-established, or preempted by concurrent social norms, but also because methodological norms are also, at least to a certain degree, *products* of actual research practices and will thus evolve over time (Longino 2001). As compliance to methodological norms presupposes adequate systems of social incentives and sanctions for researchers, so successful cognitive integration processes can only take place in settings of compliance to certain social norms. This is how social integration becomes *methodologically* relevant. Secondly, stakeholders will cooperate successfully with scientists, not just because they share interests or expertise (in transdisciplinary projects, they often do not), but also because they may have learned that, regarding complex and ill-defined issues, substantial cooperation often produces the best results–not least because it contributes to social cohesion which may further contribute to cognitive cooperation. Social cohesion, however, can never be based on cognitive aspects alone but at best on a combination of the latter and a commitment to shared social norms and the underlying moral or cultural values. Therefore, the establishment of social capital within heterogeneous groups is a prerequisite for successful cognitive integration in transdisciplinary projects.

In what follows we will only be concerned with cognitive integration and the role of knowledge in integrative processes. According to the distinction between transdisciplinary knowledge production in a narrow and a wide sense, different kinds of cognitive integrative tasks are to be expected. We are going to distinguish tasks in three areas of cognitive integration processes.

Integration Between Domains of Scientific Analysis

Research questions (i.e., questions that are directly amenable to methodologically restricted knowledge production) can be located within one of the four domains of analysis. They will *either* address structures and properties of (material or conceptual) systems; *or* they will address the goal-directed assessment of such structures or properties, *or* the inquiry about the underlying schemes of goods and values implicated by such assessments, *or* the assessment of actions suggested by the results from domains 1 to 3. Furthermore, research questions necessarily need to be formulated by specifying ontological domains and the adequate methodical approaches that allow for the resulting knowledge production. However temporary such boundaries may be, *at any given time* there will be a specific ontological domain associated with a specific set of methodical options and the underlying methodological norms that represent the formal context of each research question. Consequently, there will be strong divisions of labor regarding knowledge production within all domains of analysis at any given time. But since the cognitive goal of transdisciplinary research is action-oriented knowledge, and since rationally grounded action presupposes knowledge from all four domains of scientific analysis, we suggest that it is the total of the four domains of scientific analysis in problem-solving science that constitutes one area of cognitive integration.

For narrow analytical purposes regarding research tasks, this area can be viewed as composed of the set of research questions, knowledge claims, and methodological patterns involved in any one research endeavor. It is these elements that are the *objects* of integrative processes among domains of analysis in transdisciplinary research. Such objects will basically be related through implication. In order to structure research usefully among domains 1 through 4, knowledge production within each domain presupposes knowledge claims raised within the neighboring domains. Scenarios are the main means of relating these claims (see Scholz & Tietje 2002, pp. 79-116).

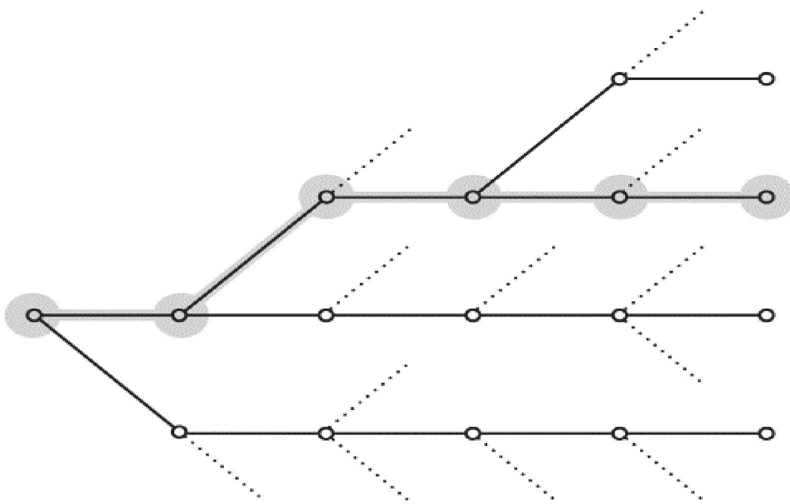

Figure 2. Scenarios. The lines represent possible histories of a system with each small circle as an event (i.e., a natural or a cultural impact). Each event may open certain theoretical or practical options regarding future histories of the system. The connected gray line is thus a graphical representation of a concrete scenario.

Scenarios enable extra-scientific stakeholders to ground their decisions practically. They also represent the research means for ontological and methodological integration. First, most research can contribute to one or several analytical tasks, although any one specific research question will exclusively address a problem within only one domain of analysis. Second, no specialty can work out reliable scenarios on its own; it needs to relate its conclusions regarding research questions within a specific domain to the results from others. Third, no cluster of cooperative knowledge production can work out reliable scenarios exclusively grounded on scientific knowledge production because scenarios also depend on the cooperation between researchers and non-scientific stakeholders (see section below on integration of non-scientific expertise). The reliability of scenarios in complex, real-world problem-contexts depends crucially on the integration of scientific analysis with the knowledge, attitudes, and perceptions of non-scientific stakeholders.

Integration of Disciplinary Divisions of Labor Within a Domain of Analysis

There are not only integrative tasks between the different domains but also within each domain. In our example, in order to explain pressures on the ecosystem one may look at, say, human impacts, land use, or water pollution. But in order to explain the driving forces of human land use, an analysis of economic needs, social norms, and their underlying cultural values, as well as further motivational drivers, is necessary. There are thus clearly cultural and social "causes" for the pressures on the ecosystem. Therefore, within the first domain of analysis natural and social scientists need to integrate the results of their respective analyses. This is feasible where assumptions regarding the *relationships* between causal, or correlative, or conceptual relations between heterogeneous domains of research can be substantiated scientifically (e.g., by propositions about the causal relationships between geographical and biological subsystems that are the subject matter of different specialties, but also about causal relations between intentionally structured social systems and ecosystems). The same applies to the second level of analysis. Assessments of system qualities may be viewed as basically twofold. One type of research may be concerned with the qualities themselves, say, of riverbeds in relation to the functionality (or dysfunctionality) of a water-supply system. Another is concerned with conceptual systems of goods and values that underlie any assessment. It is clear that the reliability of assessments may increase by means of "interdisciplinary" integration of such types.

If we want to talk about cognitive integration in science, we should also consider that bodies of disciplinary theory, and their elements, need to be formally related in order to generate synthesis. The scope of this paper does not allow for a substantial discussion of this matter. Nevertheless, the most basic options available from the philosophy of science, reductionism and functionalism, may be summarily introduced.

The first, theory reduction, is not a very promising account regarding the cognitive goals of transdisciplinary science for theoretical as well as practical reasons. Its very concept is disputed since consensus regarding its sources and applications is lacking. Moreover, the real practices of contemporary research point epistemically, as well as socially, in the opposite direction (e.g., to specialties from the biological and the social sciences) (see Nagel 1961, pp. 336-66 and 398-446; for criticism on this account see Nickles 1975; Garfinkel 1981, pp. 49-74).

Functionalism is a more suitable approach. It views the basic concepts of the biological and the social sciences as functional instead of natural terms (Fodor 1974; Kim 1998, pp. 89-120). Functional terms refer not to properties or relations but, instead, to the behavior of their referents. Given such an account, integration within an analytic domain can have the meaning of "relating causal chains to each other," or "relating different functional components to each other," or "relating causal components to functional components" (as in the case of relating systemic properties to the assessment of systems). As functionalism offers a variety of such options for relating different subject matters, we look upon it as a promising theoretical framework for clarifying the salient notion of "integration" in future research about inter- and transdisciplinarity.

Our characterization of the basic options regarding the formal relationship among theory domains is an attempt to specify how different "languages" in science can be integrated. Of course, it is true that scientists and other stakeholders involved in research or education need to avail themselves of some sort of "common language" if they are to cooperate or if they intend to integrate the cognitive elements of their work. It is also true that they often cannot mutually grasp, let alone empirically operationalize, the concepts being used or the relationships being postulated between such concepts by their respective cooperation partners. This is also a well-known predicament of communicative or integrative efforts between intra- and extra-scientific partners in transdisciplinary projects. But what exactly does it mean to integrate "languages" in research contexts? First, it is important to distinguish between linguistic translation tasks (in the sense of lexically relating different *natural languages*) and the task of commensurating *scientific languages* that are typically formal, or formally grounded languages. Although scientists hardly ever *talk* in such languages, or use them in their everyday activities, such languages are to be used whenever theory elements, hypotheses, or research questions need to be operationalized for actual research processes. Second, the esoteric languages used in scientific specialties are determined by their subject matter, by specific experimental techniques, typical methodological diversions, and so on; and all of these elements typically contribute to make the language of a scientific specialty difficult to access semantically and syntactically. Third, although the languages of scientific specialties are *instrumental* in integrative processes in knowledge production, the *actual objects of integration* are the subject matter, the experimental techniques, and the methodological diversions, and so on of the different specialties involved in research cooperation. It is precisely the methodological (i.e., justificatory) and the ontological (i.e., truth-related) functions of these objects of each scientific specialty that are to be integrated for cognitive synthesis in research.

Integration of Non-Scientific Expertise

This third area of cognitive integration will usually transcend research in its narrow sense. In action-oriented research, there will be various intra- and extra-scientific *problem descriptions, problem explanations,* as well as *practical solution proposals* that all equally represent knowledge claims concerning the cluster of issues at hand. By "expertise," we mean the professional knowledge of researchers or the gathered experiences of laypeople that result from the reflection on, or the practical everyday dealings in, specific subject matters. Non-scientific expertise then can be viewed as a specific set of knowledge claims made by certain stakeholders within transdisciplinary projects. However, such extra-scientific problem descriptions and explanations will need to be assessed in a similar fashion as intra-scientific knowledge claims in order to become instrumental for transdisciplinary research. If this is not accomplished, such claims will be unable to serve as legitimizing grounds for political decision-making as research-based knowledge claims may. Consequently, there will have to be trade-offs between the inclusion of non-scientific stakeholders and expertise (in order to ascertain the most complete problem view and knowledge production-process) on the one hand, and the submission of non-scientific expertise and knowledge claims to the restrictions grounding scientific knowledge production, on the other. It is this trade-off that carries the most ideological and political weight in transdisciplinary projects since all intra- as well as extra-scientific expertise will, at least in principle, be amenable to challenges on account of its explicitly or tacitly presupposed preferences regarding goals or value-schemes.

It is not only expertise that is to be integrated in transdisciplinary research projects, but *heterogeneous and divergent interests and value-schemes* regarding the extra-scientific issues at hand. Different problem-perspectives do not only all equally serve as adequate representations of complex life-world problems, but they also express, in most cases, the fact that there actually *are* many very different problems at issue. As has been discussed previously, "problem" is a value-laden notion in transdisciplinary science. In the example, "the" life-world problem is not reducible to the straightforward (or not so straightforward) ecological challenges that are at issue. On the contrary, the ecological "issue" may even be partly determined by further tacit, non-ecological issues. It is often the misapprehension that the issue at hand is "basically" an ecological (or political, or social, or economical, etc.) one that lets experts get involved in expertocratic decision-making because *their* "basic issue" is the issue they perceive and that matters most to them. Therefore, the integration of heterogeneous problem perspectives is called for if an *adequate spectrum* of well-defined problems is to be established.

The same applies to practical solution proposals. An inventory of tentative scenarios regarding solutions will express more than systemic knowledge. It will necessarily also refer to goals, goods, and values. Put metaphorically, scenario-building contributes to knowledge of what cannot be known–at least not in the sense of knowledge exclusively generated through empirical research. As is the case with problem-perspectives, the social integration of different value systems in order to generate an adequate spectrum of scenarios is a criterion for their reliability.

The Practical Locations of Integration Processes in Transdisciplinary Projects

Concrete integrative processes in transdisciplinary projects can be localized within a given project setting. For this purpose, we introduce a generic model of such projects (fig. 3) by abstracting from the actual organizational structure of transdisciplinary projects.

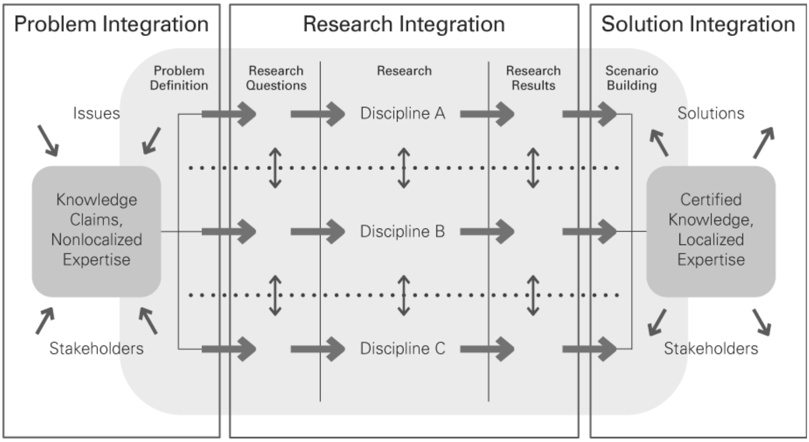

Figure 3. Flows of knowledge in transdisciplinary projects. This diagram does not illustrate the important iterative relationships between issues and research, or between preliminary results of research and imperatives for modifying research questions, and so forth.

Despite its limitations, we believe that (fig. 3) illustrates the point regarding the *localization* of cognitive integrative processes. By way of conclusion, we want to suggest three basic practical locations of integration in transdisciplinary projects.

Problem Integration.

The main *cognitive* goal that should determine activities in problem integration consists in knowledge about the transformation of life-world issues–complex, ill-defined problems–into genuine, and thus highly specific, research questions. Issues such as the ones at stake in the introductory example (general concerns for biodiversity, infrastructural, economical, and social stakes in an urban and peri-urban area) are not *directly* operationalizable in research questions since they represent an indiscriminate mix of normative and factual matters, as well as of heterogeneous and often conflicting knowledge claims. An *adequate* transformation of issues into problems that will be amenable to research will necessitate the evaluation of the relative *relevance, completeness, and epistemic status* of knowledge claims in any given case and, consequently, their integration through a systematic involvement of problem-owners and other stakeholders into problem integration. Instrumental goals of integration here consist of the preliminary assessment of non-scientific expertise and in an inventory of tentative hypotheses regarding the various subject matters and scenarios related to the issues at hand.

Research Integration

If our proposition regarding transdisciplinary research as representing problem-solving, and thus *action-oriented* research is accepted, it follows that *scenario-building* is the main *cognitive* goal in research integration in transdisciplinary research. We thus view knowledge-based scenarios (including the explication of their respective normative assumptions) as the main contributions of science regarding political decision-making and societal problem-solving. Accordingly, the integration of knowledge production within different domains of scientific analysis, and from different specialties, is the instrumental goal within research integration. In the wider sense of "cognitive integration," too, there are specific integrative tasks regarding scenario building. They involve the proper relationship between the integration of research results and their projected application in political decision-making and societal action through the integration of non-scientific expertise.

Solution Integration

Stakeholders want researchers to deliver not only scenarios but also recommendations or even concrete proposals. Two dangers are lurking here, the application gap and the legitimacy gap (see our discussion on the challenges for science). The first is usually a consequence of the negligence of some of the analytical tasks presupposed by scenario building, especially regarding the integration of non-scientific expertise. As a consequence, expert recommendations regarding extra-scientific solutions may be based less on available evidence and more on subjective preferences regarding the issue at hand (Renn 1995; Weingart 2001). For example, we have experienced that solution proposals for sustainability issues are often defended even if research actually carried out has not corroborated hypothetical links between concrete problems and their suggested causes.

A legitimacy gap may result from misconceptions regarding the role of scientists in political decision-making and societal action. The "social robustness" of the outcomes of transdisciplinary research alone, cannot *politically legitimize* their application. In Western democracies, stakeholders (including scientists) as such can, by definition, never constitute political representativeness until their principled, procedural, and institutional integration into the regular political decision-making processes has been achieved.[22] It is an inherently political task to *make decisions* among different solution-scenarios because the latter represent knowledge that is inherently uncertain as well as grounded in preference schemes that may not be explicit. The legitimacy of scientific contributions thus ends where scenarios are *selected* for according societal action. It is the task of researchers to establish scenarios based on the best knowledge available and produced within the boundaries of the previously described four domains of scientific analysis. Scientific knowledge production provides legitimacy to political decisions through the presumed rationality of the process of scenario-building. If, however, knowledge about life-world issues is inherently incomplete or uncertain its legitimizing potential is accordingly limited. In other words, science can contribute knowledge regarding systems, their assessment, and the goals, goods, and values presupposed by such assessment, *but it cannot provide either the goals or the value schemes underlying political decisions to implement such knowledge*.

Conclusion

A transdisciplinary problem is in important ways more than a need for scientific knowledge since it will involve an integration of perspectives regarding extra-scientific, societally relevant challenges. We have argued for an involvement of stakeholders in integrative processes regarding problem definition, research, and solutions that is not only balanced towards the adequate representation of intra- and extra-scientific expertise in problem-definition, but also politically balanced insofar as the weight and the potential contributions of experts will need to be carefully assessed for transdisciplinary projects to operate successfully. Since expertise is not only an epistemic, but also a social, status, cognitive cooperation and social cooperation presuppose each other mutually in order for expertise to become acknowledged epistemically as well as socially. Knowledge and skills regarding the nature of scientific knowledge, the role, the structure, and the historical and cultural constitution of science regarding extra-scientific issues, and knowledge and skills for tasks of cognitive integration are important for researchers and citizens alike. They provide key competences for all stakeholders involved in transdisciplinary research. Transdisciplinary science is a cooperative cognitive and social endeavor in a profound sense. To illuminate this sense has been a basic goal of this contribution.*

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Notes

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[1] The German concept of *Wissenschaft* does not correspond perfectly to the Anglo-American notion of "science" since *Wissenschaft* usually encompasses the social sciences and the humanities, whereas "science" is often used as referring exclusively to the natural sciences. *Wissenschaft* also interchangeably denotes the *institution* as well as the *activities* of scientists and scholars in general. In this paper, we take the liberty of using the word "science" in the sense of *Wissenschaft*. We will use the more narrow concept of "research" as denoting "systematic and methodologically restricted knowledge production."

[2] Compare to the conference pre-proceedings (Häberli et al. 2000) and the subsequently published summary volume (Klein et al. 2001).

[3] Consequently, the notable exceptions to this observation are mainly concerned with summarizing the existing uses of these concepts. Compare this, for example, with Klein (1990) and Hübenthal (1991).

[4] Wittgenstein (1953), *Philosophical Investigations*, §66. For examples of transdisciplinary projects understood in a similar way, see Klein et al. (2001, pp. 147-213).

[5] The example is mainly derived from an international project in the *Region Oberrhein* which covers the urban and peri-urban areas of Basel and its neighboring areas in France and Germany. A few elements in it

have been taken from several of the approximately 40 transdisciplinary projects in sustainability research that MGU has financed and supervised in the last 10 years (compare with http://www.unibas.ch/mgu/forschung).

[6] For a recent characterization see Kitcher (1993, pp. 31 and 74).

[7] For research on determinants of problem choice, see Gieryn (1978), and Zuckermann (1978).

[8] This problem has been at the core of discussions on the subject matter of a *studium generale* in higher education (Jantsch 1972).

[9] The Lomborg-affair may be viewed as an exemplary case; see, for example, "The litany and the heretic" in *The Economist* (2002, Jan. 31). Retrieved May 30, 2004, from http://www.economist.com/displayStory.cfm?Story_ID=965520.

[10] Nowotny et al. (2001) include the "infiltration" and "improvement" of research by "social knowledge" as a precondition for the production of socially robust knowledge (p. 167).

[11] For a summary, see Kitcher (2001, pp. 53-108).

[12] The problem is best understood as being one of a "political philosophy of science" which is still in its infancy; see Ezrahi (1990), Smith (1996), Brown (2000), Collier (2000).

[13] The classic location of the core of this somewhat disputed contention ("extension of certified knowledge" as the institutional goal of science) is Merton (1942). For a re-evaluation, see Weingart (2001, pp. 68-87). Kitcher (2001) has complemented this account by showing that science can legitimately be expected to strive for epistemic as well as practical significance in knowledge production.

[14] For an introduction to the history and the systematic position of the notion of propositional knowledge, see Moser & vander Nat (1987). Regarding the element of *truth* in the definition, we want to discriminate between a semantic (deflationary) and a qualitative (correspondence or coherence) notion of truth. Our discussion need only presuppose a semantic notion of truth (Horwich 1998). Our use of "ontological commitment" is derived from that of Quine (1948).

[15] Compare, for example, to Russell's (1912) notion of "knowledge by acquaintance," or Ryle's (1946) discussion of "knowledge how" that he contrast with "knowledge that," that is, propositional knowledge. While these and other notions of knowledge are still being discussed in contemporary epistemology the identification of "scientific" with "propositional" knowledge has not been seriously contested in epistemology.

[16] In the sociology of science (or of scientific knowledge), "knowledge" has usually been identified with "accepted belief" or "knowledge claim," if the concept of knowledge or its use is explicated at all (see, for example, Fleck 1935; Mannheim 1936; Berger & Luckmann 1966; Bloor 1976; Shapin & Shaffer 1985). For critical discussions of this identification, see Goldman (1999, pp. 3-40); Kitcher (2001 pp. 3-62).
[17] Compare to Scholz (2002, pp. 26-7).
[18] Gibbons et al. (1994), Gibbons & Nowotny (in Klein et al. 2001), and Nowotny et al. (2001) state that, insofar as "mode 2" contributes to the production of socially robust knowledge, it also contributes the *better* knowledge. These authors thus clearly embrace a cognitive (if unspecified) criterion for mode 2.
[19] The report on http://www.proclim.ch/Reports/Visions_E.html refers to similar approaches in Germany, Austria, and the US. Regarding the notions of *Systemwissen*, *Zielwissen* and *Transformationswissen* see especially theses 7-14 in the report.
[20] One point of departure for a general notion of social action is, of course, Weber's notion of the instrumental rationality (*Zweckrationalität*) of social action (1922, §1,II and §2); another source (more adequate for the present purposes) is Parsons' AGIL schema (Parsons et al. 1953) which aims to explain social action according to its functionality regarding behavioral adaption, individual goal-attainment, social integration, and cultural latency.
[21] "Naturalisms" in the philosophy of science (Kitcher 1993), epistemology (Quine 1996), and moral philosophy (e.g., Brink 1989) are examples of stances that *do* allow for the possibility of results regarding such analytical tasks. But these stances still represent very much the forefront of theoretical speculation on such matters, and none of our conclusions depend on them.
[22] Notably, Nowotny et al. (2001) discriminate "robustness" from "acceptability" of knowledge because only the former "is prospective [and] capable of dealing with unknown and unforseeable contexts" (p. 167).

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