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METHODS

Implications of transdisciplinarity for sustainability research

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ABSTRACT

In ecological economics the terms sustainable development and transdisciplinarity are closely related. It is shown that this close relation is due to the fact that research for sustainable development has to be issue oriented and reflect the diversity, complexity and dynamics of the processes involved as well as their variability between specific problem situations. Furthermore, the knowledge of people involved and their needs and interests at stake have to be taken into account. There are three basic and interrelated questions about issues to be addressed in sustainability research: (1) In which way do processes constitute a problem field and where are the needs for change? (2) What are more sustainable practices? (3) How can existing practices be transformed? To treat them properly, transdisciplinary research is needed. The emergence of transdisciplinary research in the North and the South is described. By distinguishing analytically among basic, applied and transdisciplinary research the challenges that have to be tackled in transdisciplinary projects are analyzed.

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1. Introduction

The declaration on sustainable development by the world's nations at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 was most important for the commitment of researchers to tackling the problems of society in the 21st century (Funtowicz et al., 1998; Cetto, 2000). The Rio conference adopted the definition of sustainable development that was put forward by the World Commission on Environment and De-

velopment (WCED) in its 1987 report 'Our Common Future'. Following that definition, sustainable development is committed to meeting present and future needs impartially while taking into account limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs (WCED, 1987, p. 43). Promoting sustainable development therefore necessitates overcoming narrow preoccupations and compartmentalized concerns by changing technologies and institutions to achieve what is needed in the light of the

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environment's ability to meet present and future needs and equity among people.

Concerned scientists such as Jane Lubchenco in her Presidential Address at the Annual Meeting of the American Association of the Advancement of Science in 1997 argued for a new social contract for science: a commitment of scientists to devote energies and talents to the new and unmet needs of society to move towards sustainable development (Lubchenco, 1998). To be effective in coping with the challenges of sustainable development, changes in practices and institutions have to be based on reliable knowledge, which entails transgressing disciplinary boundaries. This is reflected in the definition of the term transdisciplinarity in ecological economics: 'By *transdisciplinarity* we mean that *ecological economics* goes beyond our normal conceptions of scientific disciplines and tries to integrate and synthesize many different disciplinary perspectives. One way to do this is by focusing more directly on the problems, rather than the particular intellectual tools and models used to solve them, and by ignoring arbitrary intellectual turf boundaries. No discipline has intellectual precedence in an endeavor as important as achieving sustainability. While the intellectual tools we use in this quest are important, they are secondary to the goal of solving the critical problems of managing our use of the planet.' (Costanza et al., 1991, p. 3).

To produce reliable knowledge for societal strategies about future possible developments, research has to reflect the diversity, complexity and dynamics of the related processes as well as their variability between concrete problem situations. By 'diversity' we mean that empirical dimensions relevant to describe and analyze processes are heterogeneous in the sense that they belong to different disciplines, and that there are plural values and norms that do not fit together in a systematic way. Diversity of dimensions is in contrast to homogeneity with respect to the disciplines involved. 'Complexity' is used for interrelations among heterogeneous dimensions or plural values/norms, thus complexity is in contrast to simplicity. 'Dynamic' refers to changes of dimensions acting together over time.

Furthermore, the knowledge of people involved and their needs and interests at stake have to be taken into account, because sustainable development is a socio-political model for societal changes. This needs intercultural dialogue for mutual learning between research and societal groups, who might belong to different cultures or subcultures. It is important that all parties involved develop their understanding of what has to be addressed in sustainable development and how this can be done while being conscious of the potentials and risks of problem solving strategies. Otherwise the application of scientific knowledge, although intended to improve the living of people, could cause severe, unintended side effects that threaten health and natural, social and economic life support systems (Funtowicz et al., 1998).

Experiences of this kind have given rise to influential social movements mainly in Western societies (Harremoës et al., 2002). In the South, research and development have been challenged by linking scientific knowledge with indigenous knowledge, on which many local actors still strongly rely and which contrasts with scientific knowledge in terms of epistemologies, methodologies and practices (Rist

et al., 2004). Therefore in the Rio conference in 1992 and again in the Johannesburg conference in 2002 the importance of science in contributing to pursue the goal of more sustainable development was confirmed under the condition that its role and relationship to society should be submitted to critical examination. Agenda 21, approved as an integral part of the convention in 1992, establishes in chapter 35 that current research should be broadened to include, on the one hand, more involvement of the public in defining long-term societal goals and formulating sustainable development scenarios, and on the other to develop methods for linking the findings of sciences with indigenous knowledge (<http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21chapter35.htm>).

Knowledge demands in society are about issues that call for change in societal practices. By 'issues' we mean complex matters, 'where facts are uncertain, values in dispute, stakes high and decisions urgent. In such a case, the term 'problem', with its connotations of an exercise where a methodology is likely to lead to a clear resolution, is less appropriate.' (Funtowicz and Ravetz, 1993, p. 744). Various terms have been introduced for this kind of research. We will use the terms 'transdisciplinarity' and 'transdisciplinary research'.

In the next section, we will describe some stages and lines of thought in the development of transdisciplinarity from a Western or Northern perspective and from a Southern perspective, which are of help in commenting on the relations between transdisciplinarity and sustainability in Section 3. To understand the challenges for sciences and humanities that arise from engaging in transdisciplinary research for meeting the knowledge demands in society for more sustainable practices, we will compare basic, applied and transdisciplinary research in this respect in Section 4 and conclude with two recommendations for research.

2. Stages and lines of thought in the development of transdisciplinarity

From a Western or Northern perspective an important stage can be dated back to 1970, when representatives of OECD-member states met to discuss principles of how to overcome the continuing specialization in research and higher education as well as in social institutions in general, which they regarded as a major source for the risks of modern civilization (CERI, 1972). According to Erich Jantsch innovations in planning for society at large in a government–industry–university triangle should include a far-reaching re-organization of higher education into an education–innovation system, because 'the classical single-track and sequential problem solving approach itself becomes meaningless today' (Jantsch, 1972, p. 101). Jantsch put forward the idea that knowledge should be organized into hierarchical systems by the coordination of four levels which he described in the following way: purposive (meaning values), normative (social systems design), pragmatic (physical technology, natural ecology, social ecology) and empirical (physical inanimate world, physical animate world, human psychological world). The coordination should follow horizontal principles within each level and vertical principles between levels and sub-levels. The

ultimate degree of coordination he called transdisciplinarity. This would be a framework for multi-level and multi-goal systems. General systems theory and organization theory as goal-oriented systems would be blueprints for transdisciplinary frameworks, because ‘the essential characteristic of a transdisciplinary approach is the coordination of activities at all levels of the education/innovation system towards a common purpose.’ (Jantsch, 1972, p. 114). This concept of transdisciplinarity is a systematically designed scientific top-down approach.

At the time when Jantsch launched his concept of transdisciplinarity, systems theory, systems analysis and modeling were advancing to become leading paradigms in natural and social sciences for describing and analyzing the risks that global change poses to life-support systems as a result of the manifold and poorly understood negative side-effects related to the increasing use of natural resources and to population growth (Forrester, 1961; Meadows et al., 1972). Despite the development of transdisciplinary transformations of science in recent years (Schellnhuber, 1999; Costanza, 2003; Max-Neef, 2005), the implementation of transdisciplinarity has not started in the way that Jantsch’s big picture envisaged, of an education–innovation system with universities as their main driver. Instead, research of this type is often located in intermediate institutions and mostly those that deal with quite specific issues to be addressed in societal problem solving, often on local but also on global scales. This is partly due to strong resistance against transdisciplinary transformations within academia, but also because Jantsch did not realize the crucial role of stakeholders in civil society. As Funtowicz, Ravetz and O’Connor put it: ‘The objective of scientific endeavor in this new context may well be to enhance the process of the social resolution of the problem, including participation and mutual learning among stakeholders, rather than a definitive ‘solution’ or technological implementation. This is an important change in the relation between the problem identification and the prospects of science-based solutions.’ (Funtowicz et al., 1998, p. 104).

In this perspective, transdisciplinary research is seen as part of a social process with strong elements from the bottom up. These social processes are about making explicit and negotiable values and norms in society and in science, and they are also about attributing meaning to knowledge that comes from science, for societal problem solving. Within such hermeneutic frameworks problem solving includes the transformation of attitudes, the development of personal competences and ownership along with capacity building, institutional transformations and technology development. Within this line of thinking, action research (Hart and Bond, 1995) is another radical concept of science, in which theory and practice should be mutually beneficial. Action research is driven by three principles. The first is the location of its starting point in social reality, i.e., people’s interpretations of reality, and therefore action research is related to hermeneutic or qualitative social research approaches. The second principle is that of action in field research, which integrates research into the promotion of social action to compare the consequences of different forms of social action. To achieve this aim, action, research and education have to form an interlinked triangle. The third principle is that of the so-

called subject status of the research object or participation. Researchers and people investigated should both research and be researched; everyone should participate in the situation and intervene to create change in accordance with their competencies. Similar principles of integrating research and social change have been developed in the South.

From a Southern perspective, what today is labeled as transdisciplinarity is closely related to the impacts of the writings of the Brazilian authors Paulo Freire and Leonardo Boff. The publication of Freire’s ‘Pedagogy of the oppressed’ (Freire, 1970) can be considered as an important step challenging economy and technology-driven development models based on disciplinary scientific knowledge. The pedagogy of Freire understands literacy education not only in terms of reading the word, but also reading the world. This means that the creation of a critical consciousness becomes an important content of development. This shift in the understanding of development was further deepened by relating it to the ‘liberation theology’ worked out most prominently by Leonardo Boff, who in 1986 published a specific methodology for working with the people (Boff, 1986). By putting education in the perspective of a transformation of social and political structures aiming for the ‘liberation of the oppressed’ he met the needs of many organizations of civil society (mainly organized as NGOs) first in Latin America (Garcia and Wey, 2003) and later in other Southern nations. By integrating the visions, goals and actions of local actors into the development agendas with his methodology of liberation education he laid the ground for a subsequent reconceptualization of the dominant top-down and transfer of technology (TOT) approaches to research, extension and technology development. Research and development were increasingly defined in terms of social and political indicators, rather than in terms of income, yield, technology or other forms of ‘modernization’. This has given rise, since the late 1970s, to the emergence of development approaches aiming to actively create equity-oriented partnerships between rural people, researchers and extension workers. A rapidly growing network of NGOs and activist organizations led first to the dissemination of those concepts and methodologies in Latin America. Due to strong commitments and financial support from public organizations and NGOs in the North the ideas developed in Latin America were transmitted also to NGOs working in Africa and Asia.

Since the mid-1990s Participatory Rural Appraisal (PRA) became a major feature of international cooperation. Experiences resulting from liberation education and liberation theology were an important source for the development of research methodologies based on broad ranges of participation of social actors conventionally considered as ‘beneficiaries’ or ‘objects’ of research (Chambers, 1994). During the last decade PRA further evolved by incorporating more explicitly environmental and ecological issues. Through this, the PRA methodology became one of the basic features of sustainable development in the South (Brutschin and Wiesmann, 2002). The North–South interaction over the development of what could be called a ‘southern version of transdisciplinarity’ generated a debate in which complementarity between southern and northern theories of social action and societal transformations is explored. Morrow and Torres show that Habermas’

theory of communicative action can provide a more rigorous theoretical framework for Freire's pedagogical ideas, while Freire develops the practical educational implications of Habermas' conception of communicative action (Morrow and Torres, 2002). A basic common element is their shared confidence in 'dialogical and reflexive learning'. In the context of North–South relationships the cognitive differences tend to clash when the interacting systems of knowledge are not aware of the epistemological foundations on which they define their values and practices. In order to reduce the risks of cognitive clashes Rist et al. (2004) therefore suggest thinking of 'reflexive learning' between actors belonging to different systems of knowledge as a dialogue between different 'epistemic communities', which are understood as a network of knowledge-based experts or groups that are bound together through causal beliefs and the sharing of notions of validity based on internally defined criteria for evaluation and normative commitments.

3. Transdisciplinarity and sustainability

Following the lines of thought in the development of transdisciplinarity, 'transdisciplinarity' is used for research that addresses the knowledge demands for societal problem solving regarding complex societal concerns. In this context 'problem solving' means addressing issues such as land degradation or diseases by improving the understanding of the issue and engaging in deliberation, research and development about why and how contested practices and institutions have to be changed. Thus transdisciplinary research is related to the common good as the basic justifying principle of societal institutions. The common good is generally understood as being the opposite of private interests. Conceptions of the common good in political philosophy and economics go back to Aristotle, for whom the common good consists in just institutions that contribute to the happiness of the citizens in securing their rights and duties. Thus the common good includes political justice on the one hand and general utility or happiness on the other. In political philosophy of the modern period, contractualism, natural law and utilitarianism give different interpretations for what is meant by the common good. Contractualism understands the common good as the demand that equity is prior to utility, while in natural law the common good is what the people strive for socially, and in utilitarianism the common good is seen as public demand that secures for everyone the pursuit of his or her private interests (Plant, 1991). It is obvious that improving practices includes deliberation about how to interpret the concept of the common good in this respect. Because knowledge about complex systemic relations is uncertain, deliberation about ends and means of societal changes also has to follow the precautionary principle, which says that, in cases of a threat which is uncertain, some kind of action is mandatory (Sandin, 1999). Taken together transdisciplinary research addresses the knowledge demands for problem solving in complex societal concerns with regard to the common good. These concerns may be related to but are not restricted to public goods, as some authors suggest (Kötter and Balsiger, 1999, p. 117).

The model of sustainable development is about change in social institutions in the direction of more equity within and between generations in opportunities to meet needs. It takes account of global change and its harmful effects on people, due to the complex interrelations among ecological, economic and social systems. Therefore, sustainable development can be regarded as an elaboration of the old idea of the common good, extending it in accordance with the precautionary principle to the global population and possible harm in a long-term perspective. The quest for knowledge in society is to find problem solving strategies that meet the needs of all affected parties. Thus sustainability research is committed to promote basic moral values such as equity with respect to meeting needs among and between generations (WCED, 1987, p. 43).

Equity is a moral ideal that concerns both individual actions and the social framework of society as a whole. This moral ideal can be variously interpreted (Frankena, 1976), e.g.: Does equity mean that everyone should get the same amount of goods? Or does equity mean that all should get enough to satisfy their basic needs? Or should a principle of maximization be implemented, whereby the production and distribution of goods is just, if future generations will be better off or at least not worse than today's generation, as discussed in economic theories of sustainability? Conflicting attitudes about sustainability policies can be related to different interpretations of justice. It is important to clear the ground of such conflicts in ethics, but of course it is not academia that has to resolve the issues but the political system. Therefore participatory approaches to deliberation and consensus building in sustainability issues, that have become influential through the Rio conference, are of major importance to arrive at just policies.

A further ethical problem arises from the fact that sustainable development involves deciding between alternative actions to satisfy human needs and improve the quality of human life. This is put into focus by the definition of the international environmental organizations in 1980: 'Development is defined here as: the modification of the biosphere and the application of human, financial, living and non-living resources to satisfy human needs and improve the quality of human life. For development to be sustainable it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long term as well as the short term advantages and disadvantages of alternative actions.' (IUCN et al., 1980, Introduction). Sustainability encompasses different kinds of values such as the preservation of the biosphere and economic and social values such as human health and well-being. According to a common way of reasoning, rational decision between competing objectives should be based on comparison of the respective outcomes, resulting in one option being either better or worse than, or equal to the others. When assessing the social consequences of anthropogenic climate change due to increased greenhouse gas emissions, in the second IPCC report, working group III referred to literature on monetary valuation of statistical lives and aggregated statistical lives across countries to measure the respective values. Because of different national circumstances, including opportunity costs, statistical lives and damages in developing and developed countries were not valued at the same level (IPPC, 1995, p. 50). These differences in valuation between developing and

developed countries were strongly contested by the public for moral reasons. But the basic question with respect to practical reason in this issue is whether and how a meaningful comparison of the various heterogeneous damages of climate change is possible (Hare, 1979; Sen and Williams, 1982).

So there are three basic questions about issues to be addressed in research for sustainable development: (1) In which way do processes constitute a problem field and where are the needs for change? (2) What are better practices (targets in the sense of goals of sustainable development)? (3) How can existing practices be transformed? (Costanza et al., 1997, p. 79). In addition, models are needed for how the diversity and complexity of attitudes that often conflict with each other can be negotiated in morally correct and empirically informed ways with respect to their consequences. In order to meet the knowledge demands for sustainable development, whether basic, applied or transdisciplinary research is needed depends on the kind of problems to be solved (Lubchenco, 1998; Funtowicz et al., 1998). If processes lack explanation, as in the case of ozone depletion, this calls for basic research. When there is some common understanding of which practices have to be improved and how this is to be done in a more sustainable way and how research can address the respective knowledge demands, applied research is appropriate. Applied research has to become more transdisciplinary if knowledge about how to structure complex systemic relations in a certain problem field is uncertain, and if there is dispute over which practices have to be changed and in which direction. Because the latter is often the case, transdisciplinary research and sustainability research strongly overlap and we will use the terms interchangeably. We prefer the term “sustainability research” to “sustainability science”, used as term by authors following a coevolutionarist paradigm of research for sustainable development (Kates et al., 2001). While the meaning of “science” is closely linked with the paradigm of natural sciences, the transdisciplinary aspects of research for sustainability encompass social sciences and humanities as well as the participation of societal actors. Qualitative and interpretative approaches of social sciences and humanities are needed to get to an understanding of the different views, purposes and practices held in society with regard to an issue and to develop knowledge needed in deliberation.

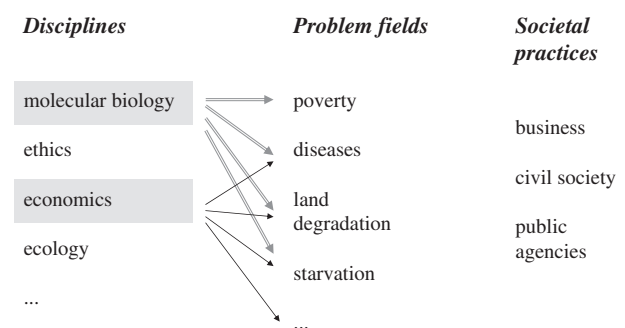
When research gets more transdisciplinary, researchers enter unfamiliar grounds for scientific knowledge production. In facing the complexity of issues not only on the empirical level but also with regard to the purposive, normative and pragmatic level of societal problem solving, research gets intertwined with societal practices and policies, thus challenging the nature of scientific knowledge and opinions about its quality. For a better understanding of these challenges, we will compare transdisciplinary research with basic and applied research with regard to the quality of knowledge and the relation between scientific knowledge and societal practices.

4. Problem identification and problem structuring for research

In their 1993 paper Funtowicz and Ravetz not only use the two attributes of systems uncertainties and decision stakes to

distinguish among core science, applied research, professional consultancy and post-normal science, they also characterize these types by their goals: ‘applied research is “mission-oriented”; professional consultancy is “client-serving”; and post-normal science is “issue-driven”. These three can be contrasted with core science—the traditional “pure” or “basic” research, which is “curiosity-motivated”.’ (Funtowicz and Ravetz, 1993, p. 740). We develop their ideas somewhat further by distinguishing among three types called basic research, applied research (including professional consultancy) and transdisciplinary research according to how academic disciplines on the one hand and society on the other are engaged in identifying and structuring problems for research. The analytical classification is intended to serve for a better understanding of the challenges that researchers have to face in transdisciplinary projects while keeping in mind that boundaries between the three types are fuzzy, and interpenetration of types stimulates mutual benefit. To distinguish between the three types of research in Figs. 1–3 we use a three-column diagram that adapts Elzinga’s concept of the four policy cultures in his analysis of driving forces in global change research. Elzinga distinguishes between a scientific, a bureaucratic, an economic and a civic policy culture (Elzinga, 1996). In the diagram the column in the middle lists some problem fields. The column on the left lists some disciplines of sciences and humanities. Scientific disciplines such as physics and chemistry, but also disciplines such as economics, jurisprudence and ethics for instance, emerged as primary units of internal differentiation of science, humanities and philosophy by the establishment of their own communication systems, which started in the German universities of the 19th century. Members of a discipline share common questions, concepts, methods and standards for research, and have common institutions such as journals, textbooks, educational programs, etc. The column on the right lists social practices by distinguishing among those of business, civil society and public agencies on national or international levels. Arrows indicate the perspectives for reducing diversity and complexity in problem fields.

Although basic research can also address problems which have their origin in practical life, what is identified as a scientific problem in basic research depends on the state of the art within the discipline. Problem fields such as poverty, diseases,



Problem/Problemsolving: describing and explaining processes by general models

Fig. 1—Identifying and structuring problems in basic research.

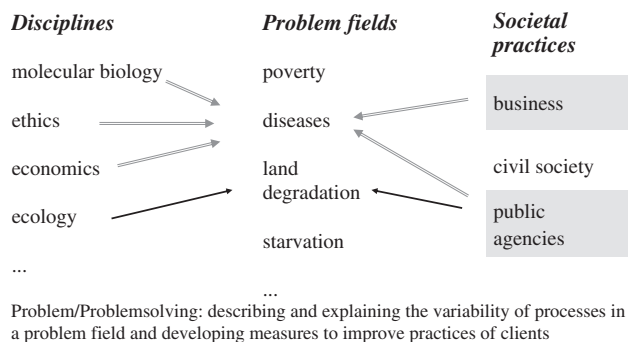


Fig. 2—Identifying and structuring problems in applied research.

land degradation, starvation and others are of interest for basic research, if they are related to conceptual or methodological problems for a discipline to describe and explain processes by means of models and methods, which are taken to be universally valid under controlled conditions. Therefore, processes of scientific interest in a problem field are identified and structured in the paradigm of the respective discipline that ignores other dimensions, which are the subject of other disciplines. In the case of diseases for instance, there are biological processes identified as a problem for molecular biology, which will not concern itself with cultural practices or economic conditions that contribute to causing diseases, but which are a subject for investigation by other disciplines (see Fig. 1).

Efforts in scientific problem solving can benefit from borrowing or combining concepts and methods from different disciplines to overcome a blockage in research or move into new productive areas of research, which is called mode 1 interdisciplinarity by Bruce and coauthors (2004, p. 460). Interdisciplinarity is a major driving force in scientific innovation that can lead to a restructuring of the landscape of disciplines by a paradigm shift within disciplines or by the emergence of new disciplines (Kuhn, 1962). Basic research is not directly linked to societal practices, but it can be useful for the purposes of practical life, because it creates grounds on which applied research and transdisciplinary research can build. Conversely, problems arising in applied or transdisciplinary research can stimulate innovation in basic research.

In applied research one or more disciplines specialize in a certain problem field. Examples would be agricultural ecology, specialized for instance on problems of land degradation in agriculture, or molecular biology, economics and ethics applied to diseases to better understand variable processes in the field to help develop measures for mitigating or solving problems. Applied research can be linked with client-oriented professional consultancy to improve the effectiveness of practices of such clients as companies or public bodies (see Fig. 2).

Applied research and professional consultancy benefit from collaborative activities and mutual learning between researchers and practitioners, as in the analysis and management of land degradation or in the analysis and medical therapy of diseases. In these cases, problem identification and structuring are guided on the one hand by a disciplinary par-

adigm or an interdisciplinary map, which needs adaptation to concrete problem situations. This can be done by adding further variables from other disciplines to tackle diversity and complexity in the search to explain the variability of processes in the problem field and for the development of management strategies, called mode 2 of interdisciplinarity (Bruce et al., 2004, p. 460). On the other hand, identification and structuring of problems can also reflect the practical problems of certain clients and the meaning that they give to the problem. So problems in applied research can be solved by structuring them according to a disciplinary paradigm or an interdisciplinary map, and by focussing on the practical problems of certain clients, which helps to reduce complexity in developing strategies to solve problems.

Abstracting from empirical complexity in concrete situations is unavoidable to achieve universality of causal models or general models of systemic relations. But because of idealization in laboratory research, scientific knowledge runs the risk of unintended and perhaps unknown negative side effects, when put into practice in complex concrete situations, which is illustrated by ozone depletion due to the use of chlorofluorocarbons in commodities. To face the complexity of concrete situations, research for societal problem solving has to transcend disciplinary boundaries and laboratories (Krohn and van den Daele, 1998). Further risks arise when the knowledge of people in society and the meaning that they give to problems, purposes and practices are neglected and therefore problem solving strategies do not meet the needs of people and their circumstances with regard to the common good; or they are poorly understood and not adequately used. The importance of a participatory evaluation of the present situation and the related 'core problems' to be addressed by a transdisciplinary research program can be illustrated from the work of the "Swiss National Centre of Competence in Research North–South" (NCCR North–South). This internationally operating research network aims to understand the 'syndromes of global change' as a basis for mitigation strategies to help sustainable development. The research agenda was set through development related multi-stakeholder meetings at a regional level concerning West Africa, East Africa, Horn of Africa, South East Asia, South and Central America. This allowed explicit regional specificities to emerge, avoiding overrated perceptions of global change biased by single or more powerful politically or scientifically

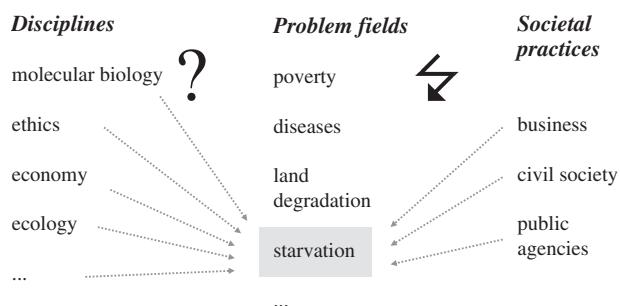


Fig. 3—Identifying and structuring problems in transdisciplinary research.

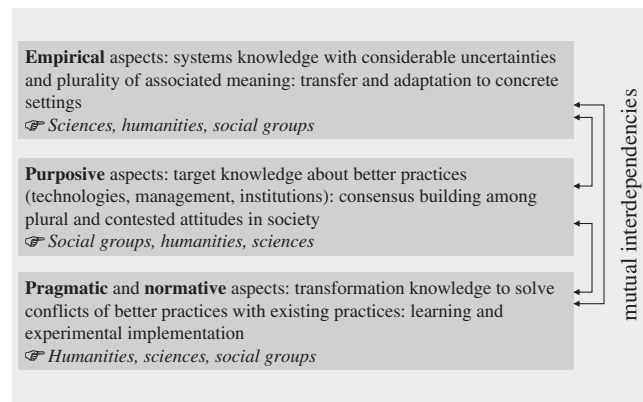


Fig. 4–Integrative and recurrent collaborations among disciplines and social groups in transdisciplinary research for societal problemsolving.

defined ‘epistemic communities’. Assessing the acuteness of 30 regionally identified and defined ‘core problems’ of global change, showed that most of the problems are related to 1) incompatible and fragile economic systems, 2) lack of adequate infrastructure such as transport, energy and irrigation and, 3) contradictory policies and weak formal institutions (Messerli and Wiesmann, 2004, pp. 418–19). This analysis made clear that global change is seen as a challenge for a comprehensive and trans-sectorial societal, rather than a technological, development. This questions the manifold technology and sectoral oriented development programs, such as huge investments in the development of high yielding crop varieties, mechanization of agricultural production, isolated attempts aiming to improve access to credits, pesticides and other external inputs for the commodification of food, fibers and services as well as conservation oriented programs for biodiversity, water and soil protection.

When societal practices related to a problem field are strongly contested, and when it is uncertain how to structure problems for research, as indicated by the lightning sign, question mark and arrows in Fig. 3, applied research has to be developed in a more transdisciplinary direction to reach valid results. The transition from applied to transdisciplinary research is gradual, according to the degree of complexity of purposive, normative, pragmatic and empirical dimensions that are taken into account in identifying and structuring problems, in investigating and developing problem solving strategies and in implementing results (Pohl and Hirsch Hadorn, 2006). When identification and structuring of problems transgress disciplinary paradigms and transcend the practical problems of certain clients, then scientific problems that are soluble thanks to disciplinary paradigms of problem structuring, and practical problems that are soluble for clients thanks to restricting the range of interests taken into account, are turned into issues that conventionally trained scientists and societal actors can often only grapple with (see Fig. 3).

In the context of sustainable development, transdisciplinary research addresses a problem field by identifying the diverse dimensions of the question at issue, and investigates their complexity, dynamics and variability with regard to how they can be transformed in a more sustainable way. The attitudes of the various stakeholders also play an

important role in identifying and structuring issues for research, because these issues are related to human practices. The consequences of these practices can affect individuals in a multitude of direct and indirect ways insofar as their needs and interests are at stake. To know the relevant dimensions one also has to learn in which ways the interests and needs of the range of stakeholders are affected by certain practices and their consequences. Participation of societal groups in research is of valuable help in this respect. This is the reason for sometimes making participation of societal actors a part of the definition of transdisciplinarity (Lawrence, 2004, pp. 488–89).

Transdisciplinary research has to encompass empirical, evaluative and instrumental aspects, which we call systems knowledge, target knowledge and transformation knowledge. The terms are coined in ProClim (1997, pp. 15–20). The empirical dimensions of the genesis and possible further developments of the issue cannot be causally explained by some universal model, because a valid understanding of concrete problem settings does not allow abstraction from the diversity, complexity and variability of dimensions involved and their dynamics. Knowledge achieved in transdisciplinary research about empirical processes is largely based on empirical evidence, consisting of data, which can be structured as systems knowledge with the help of statistics and mathematical modeling. Although the generation of systems knowledge can be methodologically sophisticated, such models lack the explanatory power of basic and applied research, and they contain considerable uncertainties. In addition, one has to learn about the meaning that societal actors in the problem field give to the processes under investigation. As a consequence knowledge achieved in transdisciplinary research does not conform to the ideal of scientific knowledge as universal, explanatory and proven. Nevertheless some kind of generalization is important, otherwise transdisciplinary projects would be restricted to counselling and lack a core element of the mission of research, namely to find out what can be learned for other problem situations. Generalization of knowledge can be achieved by transferring models and methods to other contexts and other types of issues, which needs careful validation of the knowledge in each setting (see Fig. 4).

Furthermore, plurality of norms and values within society as well as strong private interests of societal actors give reason for ongoing deliberation about concrete purposes for sustainable development, which gives a somewhat arbitrary character to the so-called target knowledge. To come up with reasonable practical applications for sustainable development, it is important to improve and communicate the knowledge base on empirical and pragmatic aspects of alternative ways of problem solving, to establish modes of consensus building in the spirit of Habermas' theory of communicative action and to elaborate ethical arguments in humanities that can be of help in deliberation among societal groups with regard to the common good.

Because of uncertain empirical knowledge, contested purposes and habits related to existing practices, it is also contested whether and how practices and institutions should be changed for sustainable development (transformation knowledge). It is important that practitioners get prepared for changing practices, that they learn about the potentials and risks of problem solving strategies and that they develop competences for implementation and monitoring of progress so as to adapt strategies and sometimes also purposes. This is of influence on what is taken as a problem solving strategy: from the implementation of definitive (technological) solutions into social learning about problem solving strategies including technology design and institutional structures, but also changing attitudes. Quality assurance of knowledge produced in transdisciplinary research has to take account of mutual influences between the empirical level of systems knowledge, the purpose level of target knowledge and the pragmatic and normative levels of transformation knowledge. This needs collaboration of researchers and social groups for recurrent validation and adaptation of empirical models in concrete situations, recurrent efforts for consensus building about purposes and recurrent implementation, monitoring of effects and adaptation of transformation strategies (Krohn and van den Daele, 1998).

The need for such collaborations gets obvious, when looking at the strong resistance to changing institutions in a more sustainable direction at all scales of society, for instance when problem solving strategies that have been developed are not used. This can be due to the expected consequences of the measures that have been recommended, that affect certain interests and needs. Therefore it is crucial that interrelations between purposive, pragmatic and empirical aspects are reflected with respect to how practices and institutions can be transformed. If more sustainable options are to be promoted, the following questions have to be addressed jointly: What are more sustainable practices? What are the conditions that might keep people from adopting more sustainable practices and what are conditions that might support them in adopting such practices? Are there effective strategies to overcome these restrictions? This is a way of reasoning, which is familiar to practitioners. But addressing these questions in a scientific, i.e., systematic way enables researchers to reveal the biases of the actors involved (Maier Begré and Hirsch Hadorn, 2004).

To determine what makes people change their practices is an interdisciplinary challenge, which can be illustrated by looking at consumer behavior. Psychologists for instance an-

alyze the different patterns of consumer motivations by referring to a constant selection of goods offered in shops. The business scientists are interested in how consumers react to which goods and how they are offered in shops, while neglecting that there are different motivational types. To get the whole story, one cannot just merge their findings because the psychological results are no longer valid if certain variables are no longer controlled, but vary with changes of the goods that are offered. In such cases, it is not just the results, but the concepts and methods of different disciplines that have to be adapted to each other and combined for research with an interdisciplinary issue-oriented approach. It is helpful to realize this process of combination and adaptation of the concepts and methods in close interaction with consumers, traders and producers etc. in order to learn about why they choose in the observed manner and to contribute to reflecting on the positive and negative effects on sustainability of all relevant actors involved in the issue of more sustainable consumption.

Because institutional and behavioral changes are part of the strategies aiming for more sustainability, transdisciplinary research has to address changes that are going beyond optimizing existing institutions (single loop learning). Transdisciplinary approaches to research and development are therefore aiming also for the support of 'double loop and deuterio learning' which means changing the structures of institutions and also assuring further development through a critical evaluation of the outcomes of the adjustments, so enhancing the capacities for learning in the future (Argyris, 1996).

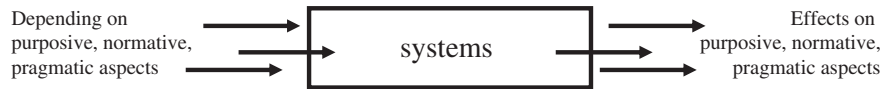
5. Conclusions

A broad range of approaches addressing issues in transdisciplinary research has been developed (Hirsch Hadorn et al., 2002). A lesson to be learned from these is not to get lost in diversity, complexity and variability. The first recommendation is about how to focus on selected problems to come up with the challenges of complexity. There are three basic questions about issues to be addressed: (1) In which way do processes constitute a problem field and where are the needs for change? (2) What are better practices (targets in the sense of goals of sustainable development)? (3) How can existing practices be transformed? One can focus on one of these questions while taking into account that each of them is related with empirical, pragmatic, normative and purposive aspects (see Fig. 5).

Investigations of why and how processes occur, and where the needs for change are, have to relate the analysis of systemic processes to purposes and societal practices, on which they depend and which they influence. These include an understanding of people's attitudes. Investigations of targets in the sense of better practices have to take the systemic conditions and consequences as well as existing practices of actors into account when designing desirable practices. This needs participatory approaches. Investigations of how existing practices can be changed and options implemented have to take into account the purposes of actors related to their existing practices and the systemic

(1) Why and how do processes occur and where is change needed: empirical level?

Analysis and valuation of processes in empirical systems related to purposes and practices

**(2) What are better practices (targets): purposive level?**

Analysis and valuation of targets related to states of empirical systems and practices

**(3) How can existing practices be transformed: pragmatic and normative level?**

Analysis and valuation of transformations related to empirical systems and purposes

**Fig. 5 – Structuring complexity in transdisciplinary research.**

conditions and processes for change. In this context, it is important to respect people's rights for self-determination together with how their attitudes are influenced by their environment.

The second recommendation for research concerns a divide in sustainability research for understanding of sustainability transitions, which can be called the 'the Scylla of political irrelevance and the Charybdis of technical inadequacy' (Guston and Sarewitz, 2002, pp. 96–97). Scylla is the optimizing fallacy. It consists of the idea that simply thinking in the tradition of systems engineering is effective in sustainable development. The optimizing fallacy neglects that research has to be concerned with the rationality of the purposes and of people's right for self-determination as well, which means that arguments for the political debates have to be provided. Candidates for the optimization fallacy are often found among researchers in natural sciences and economics. Charybdis is the participation fallacy, which neglects that democratization of decision-making does not necessarily take the limits of our life support systems into account. Political scientists and people from humanities are at risk for the participation fallacy. The fallacy in both cases is the same: it consists of taking a necessary condition for the sufficient one.

The fallacy arises because there are cognitive barriers between researchers from different scientific cultures. In an oversimplification, which shows the crucial point, one can say that research in natural sciences has an emphasis on measuring and modeling data and conceives social change as modifying variables according to the detected functional dependencies (Schellnhuber, 1999). Research in social sciences and humanities has an emphasis on analyzing concepts and theories about how to understand a problem and conceives social change in terms of self-determination of people in political deliberation. Because of basically different cognitive styles and standards the mutual expectations about sound research are not met. Partners have to become acquainted with and develop respect for the other 'culture', if they really

want to engage in joint research. The analysis of collaboration among researchers from the natural and the social sciences in a Swedish and a Swiss research program has shown that simple pressure to produce usable results does not turn Detached Specialists into Engaged Problem Solvers, but tends to modify interdisciplinary collaboration to take the form of division of labor (Pohl, 2005). This shows the importance of capacity building in sustainability research in order to develop institutions to undertake research and education in issue-orientated transdisciplinary directions complementary to existing institutions in basic and applied research.

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