Transformations of Social and Ecological Issues into Transdisciplinary Research

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Contents

Glossary

Agency problem: An expression of a necessity, of the wish to act, and the need to overcome difficulties. Agency problems are problems of doing, knowing, valuing, or saying.

Discipline: A limited social and cognitive unit of knowledge production in science with a common set of research questions, methods and theoretical knowledge. Disciplines prescribe an initial understanding of the subject matter, cognitive interests, constructions of reality and world-views

Integration: Relating and reshaping of fragmented human activities or heterogeneous components of systems, thus facilitating coordinated action, sustainable continuation of processes, and ordering of differentiated knowledge.

Interdisciplinarity: An attempt to integrate the concepts, methods, data, or epistemology of multiple disciplines around a common problem, theme, or idea.

Interest: A pattern of needs, motivations, feelings, interpretations, and intentions directing actions of individuals and groups.

Multidisciplinarity: A combination (by addition) of various stocks of discipline or profession based knowledge, concepts, methods and tools, oriented towards a theme or problem.

Orientation knowledge: Knowledge about undesired states of the present, visions of a desired future, and goals for common action.

Problem: A problem arises out of a problem situation when actors became aware of a discrepancy between their interests and the conditions of their action. A problem is a discursive expression of a problem situation.

Problem situation: A social situation in which there exists a discrepancy between the interests actors have in acting and the conditions of their action. Given ends cannot be reached under given circumstances with the knowledge available and the natural, temporal and social resources on hand.

Problem transformation: Changes in form or structure of a problem situation that make it possible to scale-down the problem as originally formulated and to generate new but different problems.

Problem of second order: Consequences and side effects of successful problem solutions that can themselves become an active element of a problem complex, thereby setting a crisis in motion.

Research problem: A problem situation has to be reinterpreted as deficit in information or knowledge within the frame of reference of a science. Research problems are determined by the already available knowledge and the applicable methods and have to be focused as questions for unknown knowledge.

Social-ecology: A science that studies the relationship between people and their natural and social environment within the normative framework of sustainability.

Socio-ecological transformation: An intentional or structural change of societal relationships to nature.

Societal relationships to nature: Patterns and practices for the material regulation and cultural symbolization of relationships between society and nature within production, consumption, nutrition, mobility, and reproduction.

Sustainability: A normative concept for the valuation of actions, processes, systems and structures with respect to long-term reproduction and evolution of society and nature. The concept is oriented toward preservation of life-support systems, intergenerational and international justice, as well as on quality of life.

Sustainable development: Development of societies within a corridor of sustainability.

System knowledge: Knowledge about the structure and function of complex dynamical systems with regard to sustainability and problem oriented action.

Transdisciplinarity: Dealing with complex problems that have extra-scientific roots in a scientific manner while working with networks of researchers and social actors. It aims at solutions to agency problems and at an overarching integration of scientific and action based knowledge as well.

Transformation knowledge: Knowledge about useful methods and concepts for goal oriented actions and about conditions for socio-ecological transformations.

Summary

The possibility of redirecting life support systems towards sustainable development is analyzed from a methodological point of view . Socio-ecological transformations at global, regional, and local level are defined as general object of this new type of research. The scientific and technological knowledge needed for an understanding of these transformations is distributed over a broad spectrum of disciplines and professions committed to incommensurable values, different theoretical concepts and conflicting methodological orientations. Therefore, a strong demand for integrated knowledge has arisen with the aim of improving both explanatory power and usefulness for problem solving. Employing a distinction between three structural levels of discourse a methodological framework for sustainability oriented research is sketched. The levels of discourse are: a normative discourse on definitions, criteria, indicators and goals; an operative discourse on strategies and actions; a descriptive discourse on states and processes of socio-ecological transformations and crisis. At each level a complex web of problems, methods and knowledge is identified. With help of a formal concept of problem a process model for the transformation of agency problems of everyday life into scientific problems is elaborated. The conditions for a cognitive integration of problem solutions are investigated.

1. The emergence of transdisciplinary research for sustainability

Human life and societal development depend strongly on the functioning of a highly complex set of interactive natural and social systems. *Life support systems* for water, energy and food are embedded in a fragile natural environment which require intelligent regulation in order to satisfy the needs of a growing population now and in the future. Life support systems establish ecological, economic, and social minimum conditions for the continuation of societal life. These systems are threatened worldwide by human agency. Alarming problems arise and then develop into crises: Shortages, and the uneven distribution of resources, pollution of air and water, degradation of soils, deforestation and loss of biodiversity, global warming and ozone depletion are global symptoms of an unsustainable world, as an emerging world society interacts strongly with a global ecology. Since the 1992 Earth Summit in Rio, *sustainability* has become the slogan for a discourse committed to the conservation of natural resources, the quality of life and a sense of obligation toward future generations, a discourse that is also steeped in controversy.

To ensure as far as possible that current generations do not diminish the availability of resources for future generations, political and economic strategies have been developed for coping with the tightly linked challenges of an unsustainable world. New knowledge constructing practices and new technologies for an intelligent regulation of life support systems have been worked out. Yet this momentous global challenge has still not been sufficiently met. This challenge also defines the key problem of sustainability research in general: How is it possible to redirect an unsustainable world towards sustainable development? We can call this challenge the *problematic of socio-ecological transformations* at global, regional and local levels.

Until recently social science approaches in particular have not been incorporated seriously into the mainstream of environmental research. Environmentally oriented specialty fields have arise within economy, law, sociology, psychology or education. In many cases the social sciences have been put to use for purposes of communication and management. Therefore, as far as sustainable development is concerned, we still depend on a strongly fragmented knowledge base. Scientific and technological knowledge is distributed over a broad spectrum of disciplines and useful applications committed to incommensurable values, different theoretical concepts and conflicting methodological orientations.

Together with the attempt to transcend the inadequate system of discipline-ordered knowledge within sustainability oriented research a strong demand for *integrated knowledge* has arisen with the aim of improving both explanatory power and usefulness for problem solving. There is also a broad spectrum of transdisciplinary knowledge outside the academic world that has been created within industrial production. This knowledge is, in part, classified to insure competitive advantage.

1.1 The constitution of discursive objects

Sustainability oriented sciences merge with various forms of problem-focused cross-disciplinary research by combining perspectives, knowledge and methods from different disciplines ('multidisciplinarity') or by referring to shared problems at the interface of different disciplines, coupled with an exchange of knowledge aimed at common solutions ('interdisciplinarity'). But the main change has been that the *problems* dealt with can no longer be related easily to the traditional subject matter of one or several established disciplines. This means they demand definition and solution beyond the boundaries of the system of disciplines ('transdisciplinarity').

This type of research is not defined by a distinct 'material field' in the sense of a set of concrete objects, as, for example, zoology is concerned with animals. Instead, it selects from a broad spectrum of phenomena those qualified as obstacles to sustainable development. But these phenomena do not form a homogeneous field of 'subject matters', as the physical and chemical properties of bodies do in physiology. Quite the contrary, a heterogeneity of subject matters characterizes the field.

From a methodological point of view a clarification of the concept of *problem* and an understanding of problem solving processes is crucial. Sustainability oriented research constitutes its 'objects' by referring to socio-ecological transformations within the normative framework of sustainability. This normative orientation functions as a problem generator. Within the framework of sustainability, natural and social phenomena convert into discursive objects that exist as problems only within the discourse so constituted. They are neither immediately perceptible by the human senses nor given by empirical observation, but are instead contested and frequently ill defined tangles of data and interpretation. Such discursive objects may appear as conspicuous phenomena, such as stinking waste, or as an issue of public irritation and protest, such as BSE. But this occurs only if we seek to reconstruct their genesis in the past and forecast their possible development in the future, while at the same distinguishing between their physical and cultural aspects; waste, for instance, is constituted as a problematic socio-ecological 'object' for research on sustainability.

The aim, moreover, is not merely to explain the unsustainable world but to intervene in its problems directly – for instance, with an economic strategy for the reduction of industrial waste. For the system of science such problems are exogenous, yet they remain pressing and call for political action or, perhaps, a technological quick-fix. To define and solve these problems in a scientific way we have to cross the boundaries separating disciplines, leaving their cognitive constraints and their traditional subject matters behind. Both the process by which exogenous problems are reconstructed as susceptible to scientific intervention and the ways in which science based solutions are introduced into the various arenas of agency need careful investigation. During the last decade, especially in Germany, Switzerland and Austria, the term of choice for this type of research and problem solving has been *transdisciplinarity.* In environmental science, research on global change, social-ecological research, technology and risk assessment, 'transdisciplinarity' indicates a transformation in the relationship of science and society. It has also been described as a "new mode of knowledge production," – one that takes place primarily in the context of application, within heterogeneous and highly diverse organizational settings, and which involves socially accountable and reflexively performed activity.

Thus, the issues involved in socio-ecological transformation require a transdisciplinary approach. A new and contested discursive field of *transdisciplinary research for sustainability* has emerged in the last decade. Within this field a variety of projects and programs with innovative concepts and research designs have been initiated and to some extent evaluated. But at the same time highly complex theoretical and methodological questions have emerged requiring epistemological reflection and conceptual clarification. The field was displayed, and its problems debated extensively, at the International Transdisciplinarity Conference held in February 2000 in Zurich, Switzerland.

1.2 The order of discourse

The field of a transdisciplinary research for sustainability functions as an attractive focal point for different trends in research on environment and development. The general aim is to treat problems of social, economic and technical development, viewed as 'non-sustainable', in a scientific manner. Non-sustainability of life support systems defines the general problem focus of research. Science is directed towards challenging extra-scientific problems. Solutions for these problems are investigated using scientific means and methods; while, in turn, the solutions proposed or put to use become the subjects of new research.

This emerging field is characterized by controversy, a terminological jungle, conceptual confusion and heterogeneous interests. In response many scholars have explored the meaning and use of the two rather murky concepts, 'sustainability' and 'transdisciplinarity,' and have proposed definitions to clear them up, thus making them useful for evaluating projects and programs. Yet a recognized conceptual framework for research is still missing.

One reason for this deficit is the hybrid character of the *sustainability* concept. It is simultaneously a political model used to argue for global change with a strong normative content and a concept used for scientific investigation. As a result, academic and non-academic actors with heterogeneous interests and knowledge interact with one another in sustainability research regularly . Each definition and each proposed conceptual framework functions, therefore, as a kind of intellectual intervention in a field of symbolic struggle, strengthening one interest position and weakening another. Sustainability research, in other words, always operates as a discursive activity in a network of knowledge and power.

Another source of conceptual confusion is the undifferentiated use of the term *transdisciplinarity* for the identification of whole modes of knowledge production, research types, programs and individual approaches. Transdisciplinary research, however, is always a highly interactive process among different researchers and social actors, organized in different phases with changing relationships among social and cognitive components. Social components (actors, situations, interests) are woven together with cognitive components (problems, methods, knowledge) within the discourse and transformed by research and action.

Slowly, a consensus has grown over the last few years that research for sustainability can only be conducted in a transdisciplinary form. What remains controversial, however, is how 'transdisciplinarity' is to be understood. Generally speaking, the viewpoint has established itself that the most decisive criterion is relevance for agency problems of everyday life. Which issues, however, are to count as important societal problems depends on given values, shifting political and economic interests and the manner in which the media portray the issue. Such issues normally are controversial, and knowledge and judgments about them uncertain.

Taking this point of view means that transdisciplinary research must continually reorient itself in response to ever changing societal demands and tasks. At the same time, however, it creates a public awareness of threats such as anthropogenic climate change, as something known only by means of scientific investigation. Transdisciplinary research achieves in this way a certain dynamic but at the cost of making it difficult to maintain its scientific autonomy. Consequently, the relationship between science and society changes decisively within the field of transdisciplinarity. Science becomes involved directly in extra-scientific political, economic or technical practices, becoming, as a result, either politicized or transformed into an economic or technical activity. Criteria, procedure and review institutions for quality control became crucial for this type of research.

There are, however, numerous definitions found in the literature where reference to extra-scientific societal problems is not decisive and, instead, emphasis is laid on the level of theoretical integration of the knowledge produced in the research process. Particularly influential in this respect was the OECD-seminar held in Paris in 1970. There, the Austrian physicist Erich Jantsch suggested an "overarching synthesis" of knowledge and action. Transdisciplinarity is characterized by Jantsch as a "higher, and more comprehensive level" of integration of scientific knowledge and human action oriented towards problems transcending scientific disciplines. The German psychologist Heinz Heckhausen, on the other hand, reserves the concept of transdisciplinarity for a form of theoretical integration of scientific concepts and methods deriving from different disciplines, functioning, as it were, as a meta-paradigm such as general systems theory and covering several disciplines.

Differences among conceptions of transdisciplinarity have often been exaggerated in an unproductive manner. These differences are used in particular to draw a sharp dividing line between theory oriented and agency oriented transdisciplinary research. Both forms of defining transdisciplinarity are found within the field of research for sustainability. Opposition between the two quickly dissolves, however, as soon as one views this kind of research as a whole as a cooperative enterprise with a division of labor, an enterprise realized in *projects*, each of which is organized into different *phases*. Disciplinary, multidisciplinary and interdisciplinary forms of working can take place simultaneously or successively within individual projects and phases, with either the practical or the theoretical orientation dominating a project or phase. However, if one accepts that transdisciplinary research is a matter of scientific activity, then *knowledge* must play a central role in every project and in every phase. Revision and improvement of knowledge remains always the goal of research. And if the research field is not to disintegrate into a collection of heterogeneous and disjointed activities then an *ordering of knowledge* is also required, a theoretical integration.

Certainly, the debate over the definition of transdisciplinarity can be written off as a mere academic game; things become serious, however, once powerful scientific organizations become involved. The set of criteria chosen for defining transdisciplinarity bears critical implications for research policy because it defines which research approaches are to be included within the field and which are to be excluded. To the extent that such definitional inclusion or exclusion has organizational, financial or personal consequences it must be characterized, just as corresponding attempts at defining sustainability, as an intervention in a discursive field fraught with effects. If, for example, direct cooperation with stakeholders from business and politics, or the implementation of research results as technical products or organizational innovations, are the defining criteria of transdisciplinarity then research projects with a strong focus on theoretical or methodological issues will be marginalized or excluded altogether.

1.3 Structural levels of discourse

Discourse on sustainability does not form a homogeneous field; on the contrary, it is dispersed over structurally separated levels. In 1972, Erich Jantsch, in his influential concept of a system for transdisciplinary science and education, distinguished among four levels of activity: a purposive, a normative, a pragmatic and an empirical. At each level he localized specific activities. The whole system is directed from the purpose level at the top, where policy making is located; planned from the normative level; technologically designed from the pragmatic; and informed by scientific research at the empirical level at the bottom.

Jantsch's model is a thoroughly top-down technocratic vision of the scientific world. For an appropriate understanding of the discourse on sustainability we need to modify this model. In doing so we can distinguish among three levels: a normative, an operational, and a descriptive level. In our scheme the normative level includes purposive activities, while the operational level is not restricted to technical solutions, and the descriptive level includes empirical, causal-analytical and conceptual inquiry and reasoning. The main difference between our scheme and Jantsch's is that scientific and non-scientific activities are not ordered in a hierarchy but, instead, distributed unevenly over the various levels, depending on the purpose and the design of research. There is no center of control. The following topological model of the levels may be used either as a framework for observation or as an analytic tool for the construction or reconstruction of research designs. A similar model was developed in 1996 at an international UNESCO-seminar.

Figure 1: Activities within the discourse on sustainability on different levels

a) *Normative level:* The idea of sustainability includes a normative vision of how to govern future-oriented action. It introduces a set of normative commitments into the discussion of the question of development or modernization that has been going on for some time and into the environmental debate as well. A call for equity is made on behalf of future generations, as well as a demand for the preservation of the natural conditions of life and the intelligent regulation of life support systems. In addition, international justice between North and South, social justice within societies, equity in gender relations and democratic participation in decision-making processes are all normative aspects of sustainability that have been frequently voiced and just as frequently contested.

b) *Operative level:* At the same time, sustainability implies a strong commitment to action aimed at reshaping the relationships between human beings and their environment. This occurs along several dimensions, ranging from cleaner technologies, the patterns of production and consumption to reproductive behavior relevant for demographic transitions. At the operative level different strategies and action frameworks for the fields of environment, economy, technology, politics and culture must be developed on the basis of general criteria of sustainability.

c) *Descriptive level:* A commitment to sustainability means that societal development can no longer be viewed without considering its natural prerequisites. The former is inseparably coupled with the latter's reproduction and evolution. The focus of research questions, therefore, will be on the socio-ecological transformations which change the patterns of interactions between societies and their natural environment. Discursive activities such as Rachel Carsons' *Silent Spring* function as early warning systems, identifying crises still outside public awareness.

A highly interactive process among researchers and other actors, with different relationships among social and cognitive components, always takes place at each structural level of discourse. Social components (such as actors, situations, interests) are together woven with cognitive components (such as problems, methods, knowledge) at each level. One can use the structural levels schema (figure 1) to analyze individual projects and programs within sustainability research more exactly or to organize the research field. For example, there are projects whose main emphasis is at the normative level. An example of this kind of project are those where sustainability goals and indicators are negotiated and legitimated, and criteria and indicators are established at the national or international level. Here knowledge of principles and procedures for justifying targets and norms is needed. Other projects concentrate on action strategies, and on the institutionally and behaviorally caused difficulties in implementing them. Thus at the operative level procedures, tools, or planned forms of goal oriented action are of particular significance. Examples here can be found in traffic or consumption research: Here we can see how empirical research about social structure, life-styles, individual and group behavior and ecological impacts have been integrated, while attempts are made to implement sustainability goals in concert with social actors. Finally, other projects concentrate their activities on description and analysis of states and processes. Here the attempt is made to understand the dynamic relations arising from the complex interaction of natural and social systems in order to identify corridors of sustainability. Earth system analysis as conceptualized recently by Schellnhuber is an advanced example of this kind of project.

Each project that is allocated in this way to a level according to its main focus also operates at the other levels, only not as robustly. The activities are focused according to research type, either on valuation and legitimization (normative level), social action, organizational and technological innovation (operative level) or description and analysis of socio-ecological transformations (descriptive level) The other levels possess chiefly an instrumental significance for the one in focus – they are simply assumed and viewed as more or less constant. Within the discourse on sustainability we can therefore ideal-typically distinguish three basic types of activities:

1. a goal-setting and valuating discourse,
2. an action and technology oriented discourse,
3. a state and process oriented discourse.

For the most part, projects in the field of research on sustainability locate themselves within action oriented discourse. At this level the research process may be oriented towards the development of new technologies or the management of successful cooperation between scientific and non-scientific actors. In the course of concrete research a different design must be developed for each of these.

2. Process models for transdisciplinary research

It is not enough to describe transdisciplinary research for sustainability as a form of problem solving by analogy with something like system engineering. Sustainability research is mainly conducted as an open and iterative process of research and action steered by contested values and vague goals. For the aim of design and reconstruction of those research processes the model of structural levels of discourse (introduced in 1.3) has to be differentiated and temporalized.

2.1 A general model for research processes

We suggest, therefore, modeling sustainability research in a way that views it as a productive and innovative system as suggested in 1971 by Toernebohm and Radnitzky. According to this model, the research process proceeds in the cognitive dimension in the form of a transformation of a complex web of problems, methods and knowledge These latter form the dynamic components of a cognitive complex that is embedded in various institutional, cultural, communicative and intellectual contexts.

Figure 2: Cognitive components of research processes

With such an abstractly conceived model one can represent the way in which science both renews and structures itself. One can also represent the manner in which the individual components of a cognitive complex mutually influence one another and are together changed during an entangled transformation process within a specific context. The institutional and communicative contexts determine the boundary restrictions on the development of science, thus constraining it. Disciplines and scientific cultures form the most important intellectual contexts for traditional research. They prescribe an initial understanding of the subject matter, cognitive interests, constructions of reality and world-views, and determine the direction of the transformation. The dynamic movement of the latter arises out of the mutual play of the 'empirical' and 'theoretical' elements found in the individual components, a mutual play that produces a focused flow of problems, data, information, conceptual frameworks, methods and tools. This flow can sometimes slow to a trickle; for example, when a mass of empirical details are accumulated which resist every attempt at theoretical explanation. In such cases, only a theoretical innovation of remarkable quality can get the flow moving again.

2.2 The cognitive order of sustainability research

As described above the discourse on sustainability is distributed across a normative level, a operative level and a descriptive level. In its cognitive dimension research processes proceed in the form of a transformation of a complex web of problems, methods and knowledge at each of these structural levels. If we distinguish analytically between these components we can construct a cross-table for the identification of cognitive activities in sustainability research. This table is a formal representation of a multi-dimensional problem-space in a two-dimensional scheme.

Figure 3: Structural levels and cognitive components of research for sustainability

Normative level: Central problems are constituted at this level by the search for convincing reasons for action goals, that is, by seeking moral principles and their interpretations, on the one hand, and criteria and indicators of sustainability in the ecological, economic and social dimensions on the other. At the same time, the feasibility of these criteria and indicators is warranted in that they are the possible outcomes of social agreements and consensus-building. These normative problems are expressions of the general goal of keeping socio-ecological transformations in a 'corridor' of sustainable development.

What is needed here, for example, are principles and methods for justifying norms ethically and warranting them as means for the empirical analysis of interests and orientations in politics; for the mediation of interests; for designing communicative tools for consensus building (for example, consensus conferences or scenario workshops for constructing scenarios for changing institutional settings); for determining risk assessment; and for the valuation of goals. The outcome of such a process will be knowledge about currently existing undesired states; visions of a desired future; goals for common action; and modified systems of criteria and indicators – in short, *orientation knowledge*. This kind of knowledge allows a valuation of states and processes in the present with respect to sustainability, estimations of risks and professional judgment of decision making in the ecological, economic and social dimension.

Operative level: Here a key problem arises: How can scientists work out, together with social actors in different fields of society, useful concepts for goal oriented actions, and who will carry out these actions? To tackle this problem we need political, economic and technical concepts and methods and instruments as catalysts for change in the direction of sustainability. Examples here include methods for investigating constraints on sustainable change; methods for estimating the limitations of control and management of social and ecological systems; and methods for calculating costs and financial requirements. The outcome here is integrated knowledge about conditions for socio-ecological transformations and knowledge about the practicability of concepts for goal oriented actions – in short, *transformation knowledge*.

Descriptive level: The hard-core problem at the descriptive level is to acquire a profound understanding of the interaction between dynamic natural and social systems and of socio-ecological transformations at different scales of space and time and different levels of organization. The new knowledge base for sustainability requires methods for empirical investigation, analysis and modeling of those systems and transformations; it also requires, however, innovative tools and strategies for integrating the practical experience of social actors and the knowledge regarding sustainability created in different branches of the natural and social sciences. The outcome of this is a new form of *system knowledge*.

How can we describe, analyze and understand socio-ecological transformations in order to identify non-sustainable states and processes, and to build a 'corridor' constrained by 'crash-barriers,' allowing for a different path to (more) sustainability? To answer this question we have to distinguish between transformations intentionally caused by identified actors and those structural changes caused, for example, by global economic or technological innovations or global ecological crises beyond the reach of local actors. The development of conceptual models and integrated empirical methods for the investigation of those interactions and transformations, at both the level of social behavior and action and that of structures and systems, is still only at the beginning. Obstacles hindering the conceptual integration of knowledge coming from diverse natural and social sciences, and difficulties of cooperation between discrete scientific cultures, are the main issues found at the descriptive level.

The above scheme of structural levels and cognitive components may be used in a recursive manner: We can analyze each field within the table by reapplying the whole scheme on this special field. For example, in the field, "methods for ethical and political justification of norms," missing knowledge about such methods leads to problems at the normative level. Thus we can differentiate between methodological and knowledge problems; between methods for solving problems and methods for integration of knowledge.

Transdisciplinary research for sustainability, however, is defined neither by the division into normative, operational and descriptive levels of discourse, nor by the distinction of problems, methods and knowledge at each level. These general distinctions constitute only a formal scheme in the shape of a cross-table that can be used to analyze any kind of research. Sustainability research gains its added particularity by specification of the problems, methods and knowledge within its domain. Within the normative framework of sustainability the distinctive move is a reference to socio-ecological transformations. Any description of the research field should be a specification of that general reference.

From a methodological point of view, questions of social and cognitive integration dominate each level of the discourse on sustainability: At the *normative* level, an integrative view with respect to the environmental, economic and social dimension of goals for action is necessary; at the same time, the social integration of different normative orientations, interests and motivations is a precondition for a normative consensus. At the *operative* level, where the conditions of actions are shaped, divergent interests must be reconciled and coordinated under consideration of ecological, economic and social constraints; while at the same time scientific knowledge must be linked to the everyday experience of different social actors in their respective social-cultural contexts. At the *descriptive* level, where activities are centered around the production and ordering of system knowledge, data, methods and theories drawn from the various natural sciences, technical disciplines and social sciences must be integrated and related to everyday knowledge and experience.

But what does *integration* mean here? Integration presupposes differentiation: Fragmented activities or heterogeneous components of systems must be reshaped in a manner that enables them to be linked more or less coherently, thus facilitating coordinated action and the sustainable continuation of processes. We see, then, that by applying a broad variety of methods and tools at each level a new knowledge base for sustainability arises: knowledge about justified and socially acceptable goals; knowledge about the capacities and possibilities for action on behalf of sustainability; and knowledge about the functioning and dynamics of complex systems. But this means that questions of *cognitive integration* become crucial for progress in the field of transdisciplinary research for sustainability.

Because of the diversification of subject matters and the fragmentation of highly specialized professional fields this discussion of knowledge integration is linked in many ways to an old but still ongoing debate about the *unity of knowledge.* Now, however, this debate takes a new turn in that the questions of *social integration* become equally important in research practices. The traditional philosophical idea of a *unity* of knowledge reflecting the internal order of nature and culture has gradually been transformed into the technical metaphor of *networked* knowledge, a kind of knowledge useful for generating problem oriented economic, social or technical innovations. The connectibility of fragmented knowledge reflects the need for cooperation and the search for coherence in a fragmented world no longer viewed as a spiritual unity.

As opposed to the mere instrumental concept of connectibility the positivist idea of a unified science, and its various transformations into cybernetics and general systems theory, Marxian and structuralist concepts of science, complexity theory and synergetics, is still to be found today. All of these are different attempts, based on various scientific frameworks, aim at an all-encompassing ordering of knowledge beyond disciplinary boundaries. Within the discourse on transdisciplinarity they function as provisional meta-paradigms for the ordering of scattered knowledge, either within a common frame of reference or as a hypothetical world-view.

3. Problems – the fountainhead of science

Society wide problems of everyday life are the starting and end point of every transdisciplinary research process. These problems must be transformed into scientific problems and then processed, with the result being the method-governed production of useful solutions. Even the roughest sketch of such a process of problem resolution makes clear the central importance of the concept of a ‘problem’ for transdisciplinary research. Problems are the dynamic moment of the process; all activities are directed at.

In an early study of the logic of problems Mario Bunge emphasized their centrality for any kind of research. Scientific knowledge is, by definition, the outcome of an investigation conducted with the methods and the aims of science. And investigation, whether scientific or not, consists of finding, stating, and wrestling with problems. It is not just that research begins with problems, research consists in dealing with problems at every step of the research process. To stop dealing with problems is to stop research and even routine scientific work.

3.1 The conceptual world of problems

But what is a problem, and what does the distinction so commonly made between problem and solution mean? Very early on it was recognized that a theory of science that placed the dynamical development of the sciences at its center without having a concept of a problem had no foundation under its feet. That such a conception is necessary has again and again been proclaimed a desideratum of method. Such a conception, it is promised, will lead to a whole new methodology for problem-focused research.

So far this has remained mostly a pious wish. There have been, however, some useful attempts to clarify the concept of a 'problem' in terms of either cognitive psychology, linguistic analysis, cybernetics, organization theory, philosophy of science or logic. We will take a look at some of these now.

Mario Bunge, writing in 1967 on the logic of problems, helped to make clear the difference between problems in science and everyday problems: Everyday problems, according to Bunge, are formulated with reference to everyday conceptions and interests, while scientific problems are formulated with reference to theories. In any problem we can identify three elements: the background; the generator of the problem; and the problem's solution, if there is one. Thus, generally speaking, we can view every problem as being posed against a certain background constituted by the antecedent knowledge and the actual interests. In order for a problem to be well formed, statements concerning presuppositions that are not questioned in the inquiry prompted by it must be accept at the outset. The background and the presuppositions together make up the context for a problem formulation.

Now, from a logical point of view, a problem is generated as a system of statements and questions: valid statements about the problem situation and the conditions for its resolution, and questions about what is unknown or unattained. It follows that values, norms and goals may be regarded as generators of problems when reformulated as questions. Finally, the formulation of a problem at the same time always sets the conditions for its solution. Thus, every problem induces a set of formulas – the solution of the problem – which, when inserted into the problem's generator, convert the latter into a set of statements with a defined truth value.

The ordinary, everyday meaning of 'problem' refers to a difficulty in which one is stuck. 'Problem' is an expression of a necessity, of the wish to act and the need to overcome difficulties. Human problems are problems of doing, knowing, valuing, or saying. This everyday understanding serves as the basis for most general conceptions of 'problem.' These conceptions are usually explicated with the aid of an means-end schema of human action. According to this schema a problem arises when an individual, or a groups of individuals, wants to reach a required or desired goal, one that is not immediately at hand but attainable only by using means and methods that are yet not available. The search for adequate means and methods therefore is a central activity in problem solving.

It should be already clear from this simple way of looking at a problem that action-related problems are dependent on goals, on empirical knowledge about states and processes, and on strategies and means for action. Actions always take place in concrete situations and follow explicit or implicit action plans. It may turn out, however, that the desired goal is not achieved, the needs in question are not adequately satisfied, the feelings of the individuals involved are hurt or the interpretation of the situation necessary for the action is inappropriate. In short, interests are violated. Such situations we call *problem situations*. In a problem situation there is a discrepancy between the interests actors have in acting and the conditions of their action. Only when actors become aware of this discrepancy does a *problem* arise out of a problem situation.

Following Parthey we distinguish conceptually, then, between a 'problem situation' and a formulated 'problem'. A problem is a discursive expression of a problem situation. Problems are, in other words, ideational-linguistic representations of those social situations in which given ends cannot be reached under given circumstances with the knowledge available and the natural, temporal and social resources at hand.

Problem situations are always given within a horizon of interests, conceptions and knowledge as their background and articulated from the perspective of various social actors. Problems exist only when they are perceived, articulated and recognized as a possible topic of discussion. Problems are discursive objects. During conflicts problems that are articulated in this manner may themselves be questioned ; they can, that is, be made the object of a meta-discourse about problems and as such criticized, repudiated, or affirmed. It is often during such problem meta-discourses that the interests of those affected first become clear. It is important to recognize that in any problem situation social and cognitive moments are woven together. Even purely theoretical or logical problems exist only if they have been articulated within a scientific community.

3.2 Socio-ecological problems

Specific cases of socio-ecological problem situations appear when social actions and ecological effects interpenetrate and are no longer separable. Limits to steering capacities, deficits in financial or technical means, too little political power, insufficient authority to act, subjective restrictions on behavior, deficits in information and knowledge, etc. are all possible causes of such a socio-ecological problem situation. Ecological dangers create new conditions for social action, raise the complexity of a situation and make it more and more difficult to distinguish between cause and effect, reality and interpretation. In such socio-ecological problem situations there is almost always a constellation of divergent and convergent interests, that is, different patterns of needs, intentions, feelings, and interpretations. If transdisciplinary research seeks to deal with socio-ecological problem situations then it will have to deal with such a jungle of thorny phenomena.

But a conception of problems that is fixated on the immediate context of action is too narrow to be able to conceptually penetrate this jungle. There are such things as '*complexes of societal problems*' that are 'objective' in the sense that they contain elements, created by social actions, that behave independently of the intentions and actions of social actors. Situation transcendent, objectively existing problem complexes, together with their underlying concrete situations and the awareness bound up with these, point to *system problems:* difficulties a system (social or natural) faces in changing from an initial state into a target state, such as a state of dynamic equilibrium or optimal adaptation.

Moreover, action problems and system problems mutually determine each other : On the one hand, the problem situations in which actors are situated are structured by the dynamic of systems, thus forming conditions of these agent's action. On the other hand, system problems and system structures emerge out of networks of actions; they are the consequences of actions. This emergence of order out of a multitude of uncoordinated actions is a prominent field of study within research on complexity, self-organization and non-linear dynamics, where system problems appear as obstacles to the reproduction and evolution of emerging systems – which is just another way of talking about sustainability and its problems.

Socio-ecological transformations also determine a complex of problems and problem-situations in this sense. They exist only in relation to an objective problem complex, while remaining at the same time always embedded in a situation that has been fashioned into a context of action and in relation to the people involved, together with their wishes, knowledge and abilities. Socio-ecological transformations are, then, never unambiguous, and this provokes continued attempts to subject them to political action by means of reduction and simplification.

Whenever a particular socio-ecological 'problem' is formulated it is conceived from the perspective of a possible 'solution'. One can then treat this 'problem solution' as an object available for manipulation to the extent that it is freed from its constitutive matrix, with the latter consisting of the needs of the social actors involved and these actors' interpretations of the situation, goals and intentions at hand. In this way the discrepancy between interests and conditions is reduced to a simple schema of means and ends. 'Available for manipulation' here means processing problems within institutional contexts of action (politics, administration, law, economy, science, education, etc.) in accordance with a particular solution model. Formulated problems define possibilities for solutions, and, conversely, with tested and successful solutions, problems get adjusted in a way such that institutionalized routines appear as solutions to problems.

Solutions to problems in this model, therefore, occur for the most part within the framework of clearly defined competencies, decision hierarchies and institutions with their available resources. For the most part they concentrate exclusively either on the societal or on the ecological-technical aspect. This can lead to an unintended, barely reparable intensification of the problem situation; in short, to a crisis. What is specific about a socio-ecological problem complex, then, is not that the societal and the ecological issues overlap and mutually intensify one another, but that the supposed solution to the problem itself can become an active element of the problem-complex, thereby setting a crisis in motion. The solution is the problem.

It is an absurd though widespread notion that solutions to problems put into practice do away with the problems to which they respond. In fact, most of the time they only transform a given problem situation into another state – a better one, it is to be hoped. If one looks, for example, at life support systems as solutions to the problem of providing individually and socially necessary nourishment, water and energy, it becomes clear that there are problems that endure and persist without interruption as long as life continues. 'Solution' here means a constant effort aimed at adequately and continually coping with an enduring problem.

One can now see more clearly what it means to turn an everyday agency problem, or an objective complex of problems and problem situations, into a *problem for research*. To achieve this a reduction is always required: The discrepancy between interests and conditions that has become an object of awareness has to be expressed as a deficit of information or knowledge. There may be a deficit in knowledge concerning the desired goals (normative problem); or in the knowledge available concerning the technical, economic, political or legal possibilities and means for dealing with the situation (operative problem); or in the knowledge concerning the natural and social conditions of the problem situation or about the dynamical movement arising from system changes which produce problems (descriptive problem). In short, an agency problem situation has to be interpreted as cognitive problem.

But despite this reduction at each structural level of the discourse on sustainability the social dimension of the problem situation still exists. Different *actors* contribute to the discursive activities at each level and *problems* have to be articulated by these actors in specific *situations*. As multiple stakeholders, decision-makers, practitioners from different academic and professional backgrounds, or affected persons they have different *interests*, goals and capacities for action, and they can either work against each other or together form networks of actors. Thus a multiplicity of situations, actors, interests, and problems form the social components of the discourse on sustainability at each structural level. Their features have to be considered for any project. Therefore the organization and coordination of research by an effective management seems crucial for transdisciplinary research.

Scientists and researcher, as actors, normally concentrate on the cognitive dimensions of the problem situation and underestimate the importance of the social dimensions. In other words, they deal with problems with the help of scientific tools and methods and generate new knowledge by scientific investigation. But not every deficit in knowledge arising within everyday agency problem situations is at the same time a scientific problem that can be dealt with by means of methodically organized research. That is why, in order to be able to counter a deficit in knowledge suspected or confirmed during research on a socio-ecological problem situation, the situation must be symbolically represented in such a manner that the deficient knowledge can be brought into a relation to gaps in the system of theoretically organized knowledge. Therefore, a translation of the everyday language description of the problem into the conceptual language of science is normally needed. In this way a socio-ecological problem situation can be reformulated as a scientific question, one which can be worked on in a particular discourse formation.

But only in few cases is it feasible to translate the problem description into the conceptual language of an individual scientific discipline. In these cases the transformation process from problem situations to research questions is relatively transparent: An issue of everyday life is made the topic of a discipline based discourse, and then either linked up with a discipline specific tradition of theory and problem processing; or the discipline based stocks of knowledge are reconstructed and made more concrete so as to fill in the knowledge deficits with respect to the problem situation.

In the first case, where it is a matter of linking up with a discipline specific theoretical and methodological tradition, we have a genuine *epistemological problem*, for it is not yet known how to close the gap in knowledge: A recognized step by step method drawn from discipline based knowledge is missing; therefore a successful solution to a problem in this case goes beyond the limits of what is known scientifically, while, at the same time, shifting these limits. Here the relationship to an extra-scientific problem situation generates a difficult intra-scientific epistemological problem. Within the problem situation, in short, there is a 'scientific question in practical form' that can be taken up by the respective discipline and its tradition of theory and problem processing.

In the second case, where it is a question of reconstructing the discipline based stocks of knowledge in a more concrete form, one can work within the given theory and with the accepted methods in order to extract the information required for a problem solution. A step by step sequence of methodic operations closes the gap in knowledge, in a manner similar to a routine physical or chemical analysis. One obtains useful information about the object of investigations (for example, about the degree of water pollution) but no new theoretical knowledge. One has here, then, a *information task.*

A successful transformation of everyday issues into research questions within the framework of a discipline is an exceptional case. But the distinction between epistemological problems and information tasks drawn from this special case is useful in other cases as well. Disciplinary problem transformations set standards for comparison within inter- and transdisciplinary research.

Knowledge about goals, transformations and systems that has been ordered in a scientific discourse (organized by disciplines, sub-disciplines and theory-complexes) can only be used by social actors and institutions to work on problems under specific condition when 'bad' interpretations of the problem situation are replaced by 'better' ones. This makes possible the formation of means-ends chains that are congruent with the interests at hand. In other words, here we have a case of the resolution of a 'scientific question in practical form' leading to action that is congruent with the interests in question.

With that, however, research finds itself right in the middle of the problem situation, and the researcher moves from being a non-participating observer to an actor within a field of knowledge and power. If researchers direct their discipline based or multidisciplinary knowledge toward established institutions of problem solving and conflict resolution, then they are normally able to transfer knowledge 'successfully' only when structural restrictions on action are no longer a topic of discussion and when their research accepts and reproduces the 'factual constraints' of the political and technical practice. The diagnosis has to be constructed so as to not exceed the therapeutic possibilities; the solution has to be constructed so as to be realizable by the user. In other words, such research is only then 'successful' when the specific restrictions, interests and definitions of the problems found in the institutional practice are reproduced in the form of cognitive elements within the scientific discipline. It has been shown that it is just this kind of research that often leads to an aggravation of socio-ecological problem situations by generating second order problems.

This path, moreover, does not lead to consistent and fruitful theoretical research questions. For this reason as well, then, research oriented toward sustainable socio-ecological transformations is rarely possible in the form of discipline based research. As a result, transdisciplinary research for sustainability is confronted with the considerable challenge of transforming the 'scientific problem in practical form' embedded in existing complexes of socio-ecological problems into research questions embedded in a theoretical context adequate to the problems under consideration.

4. Problem processing in transdisciplinary research processes

Research for sustainability is part of research focused on agency problems, in particular those arising within an unsustainable world. Generally speaking, it is situated between pure theoretical research and the informed action of professionals aimed at utility, efficiency and useful results. Because of its intermediary position, attempts are continuously being made to distance problem oriented research from both basic research and from applied research, and to emphasize its specific character.

4.1 Problem-focused scientific work

Problem-focused research is normally defined as research that answers to the needs of a specific client or that aims at providing answers to specific and well-delimited technical or agency problems. Particular results of the scientific production of knowledge – for example, analytical models, conceptual schemes, techniques and instruments – are repetitively applied to concrete and practically defined problem situations. In applied research, on the other hand, complex agency problems are transformed into manageable tasks that can be processed with existing knowledge and available methods by professionals. Here it is almost always a form of *problem oriented multidisciplinarity*, a mode of research that is also the central characteristic of such ongoing practices as engineering, medicine or social work; and which constitutes a type of science-guided technical or social practice in which various stocks of discipline based knowledge, concepts, methods and instruments are technologically, administratively or situationally combined. Since the combinations are problem specific they must be developed anew for the next agency problem. There is rarely an effort made to achieve theoretical integration. Integration of knowledge is replaced by goal oriented coordination.

Engineers, architects, doctors, social workers, teachers and therapists all work successfully within these kinds of multidisciplinary practices. They can also be applied successfully in many cases, to detailed problems within the field of research for sustainability. A need for integrated knowledge appears, however, when the social and ecological consequences and side effects of agency problems are taken account. In this case we need assessment methods and system knowledge because any successful practice must be viewed as an intervention in highly complex, non-linear systems with unknown effects.

4.2 Research as a problem solving process

With all varieties of problem-focused research the attempt must be made to so structure and manage the research process that the end-result is truly a sustainable solution to the agency problem at hand. With its claim to take real-world agency problems seriously, not simply in the sense of being occasions for inner-scientific research activities but also as opportunities to work towards a solution together with those affected by the problem, sustainability oriented research must keep the problem at the core of its activities during the research process; or, at the very least, keep it clearly in view. The participation of non-scientific actors within phases of the research process can function as a kind of insurance, maintaining orientation toward the initial problem and assuring goal-attainment.

This requirement is most clearly addressed in systems engineering. Here one works with a strongly structured process model, one copied again and again in many other areas of problem-focused research. The term systems engineering denotes management of research as well as the development and production of complex high technology for defense, aerospace, or traffic systems. Systems engineering relies on a structured, top-down iterative approach to problem solving. The goals and objectives of a client define the problems to be solved as a gap between an initial and a target state. The problem is then solved step by step. The steps include: identification of goals and objectives; identification of alternative approaches that are ranked comparatively; synthesis of alternatives in order to discover new or better solutions; selection of the 'best' solution; definition of steps to implement the chosen solution; and definition and documentation of the process that led to the decision. The entire process is steered and controlled to a certain extent by the goals and objectives, with the latter representing something like the memory of the construction process.

Systems engineering, to be sure, involves scientifically shaped professional knowledge but it is a form of applied research only in a very limited sense. In research fields such as sustainability, moreover, clear goals and objectives in the straightforward sense found in systems engineering are hardly possible. Here one uses the normative concept of sustainability as a *problem generator*. A problem generator makes it possible to transform evidence and ostensibly assured experience into open *problems*. Actors' everyday situations, such as going shopping or using transportation, appear as problem situations. Only in this way does the unsustainable world make an appearance within the scientific field of vision and only in this way do paths within the corridor of sustainable development become visible as societal possibilities. Then, in the course of the research process, solutions to problems will be worked out by means of a chain of problem transformations that make it possible to scale-down the problem as originally formulated. However, how it is possible to maintain the consistency of the problem formulation over a long chain of transformations, thereby constructing a methodological memory, remains an open question. In many cases this is a question for *evaluation*, where the whole research process is investigated as a problem solving process and goal attainment turns out to be a main criterion of success.

Given the central significance of problem transformations it is tempting to conceptualize the research process in terms of a 'temporalized' schema of problem and problem solution. 'Temporalized' here means the sequences of problem and problem solutions are temporally organized within the research process. With the spread of ideas and practices found in systems engineering, and the triumph of the computer as general problem solver, this model has established itself more and more. According to this technical model, 'problem solving' is a function of the application of an algorithm in a multi-dimensional problem space.

To view transdisciplinary research processes in terms of a problem/solution schema, and even more important, to design such processes, is an operation involving many assumptions. A crucial one involves the explication of the concept 'problem' itself. An important step is the distinction between 'problem situations' within a field of social actions and 'problems' as a discursive expression of the problem situation. Complicating the situation even more is the fact that the problems themselves must be related to *disciplines* as formative context of discourse.

There are numerous suggestions in the literature for ideal-typical process models in which the entire transdisciplinary research process is conceived as a problem solving process – either in the sense of a more or less linear sequence of individual processing steps or in terms of an iterative phase scheme with feedback. Such models start with a problem that is perceived and defined within everyday life, proceed through phases which include initially breaking down the problem, processing the resulting problem components, integrating the results of processing the component problems and then, finally, implementing the suggested solutions in the social world. In addition to the fact that it is fundamentally problem oriented, this approach distinguishes itself by setting itself apart not only from traditional discipline based research but also from an agency-oriented understanding of research in terms of applied research and engineering.

Conceptually, these process models are structured by the categories *discipline* and *problem.* Disciplinarity is understood sociologically as a limited cognitive and social unity within the differentiated system of the sciences. The concept of a problem, in contrast, remains vague, being understood more or less in its everyday sense, being made more precise only by examples. In addition, what remains unclear is how to transform extra-scientific agency problems from everyday life into a form that science can deal with. With the concept of a problem, roughly sketched above, it is possible to improve on these kinds of process model.

5. Conclusions: Ordering and renewal of transdisciplinary knowledge

Every modern science has to both renew its knowledge and structure this knowledge theoretically. If a science does not renew its knowledge, the latter becomes obsolete; if a science does not structure its knowledge, then that science will become lost in the jungle of phenomena. But renewal and ordering are not two equal sides of the transformation process. To be sure, every transformation must hold, at least for time, certain structures invariant; but modern science is innovative, allowing no eternal wisdom and no final theoretical ordering of knowledge.

As already can be observed in Bacon's program, the restructuring of modern science in the direction of innovation has also changed the individual components of the scientific process, bringing these into a new relation and making them dynamic. Science develops itself through research. This is true for the traditional discipline based sciences, and even more so for the transdisciplinary ones.

Science can only remain innovative to the extent that new research problems also continue to arise out of the complex of problems, methods and knowledge internal to it and not just in response to tasks given it from outside. For transdisciplinary research this means the agency problems of everyday life that are constitutive of it must be brought into resonance with those problems produced internally, with the opposite being true as well: internally produced problems (for example, gaps in the system of knowledge or theoretical inconsistencies) have to be brought into resonance with the agency problems.

Problems are the most important source of potential renewal for the sciences, theories the most important source for creating an ordered framework. Problems, methods and knowledge all undergo change and stabilization successively during transformation processes, to various degrees and at various speeds. And while it is true that theories have the primary function of ordering already existing knowledge, thus appearing as a relatively stable component in the process, they, at the same time, mark the borders of knowledge, thereby pointing towards what is not known – non-knowledge – and in this way indicating the scientific problems that need to be work on. Theories form a framework in which problems first become scientifically describable at all, whatever their origin might be.

Galileo Galilei, the famous sixteenth century genius, already saw that society wide agency problems of everyday life can only be transformed into questions internal to science if they are reformulated in a theoretical context. He showed how an *external problem* (for example, a disease thought to be incurable) can only be dealt with scientifically if it is reworked into an *internal problem* (for example, a problem for physiology). That is why external problems have to be reformulated with the concepts and the cognitive schematization of a theory. Then one can investigate causal connections experimentally within the artificial and simplifying conditions of the laboratory; for example, the causal connections between hygienic conditions and diseases. Such connections do not display themselves clearly, if at all, under natural conditions, since the latter are normally extremely complex. According to Galileo's proposal, then, phenomena that are perceived directly and experienced as problems are reformulated with the aid of a theory into an experimental construct; that is, worked up into material that is ready for a laboratory. In other words, external problems are reformulated according to rules and standards internal to science into internal ones.

Today, the transformation problem already present in the work of Bacon and Galileo has assumed a new and more acute form. Most of the really challenging problems of everyday life lie beyond the established subject matter of the discipline based system of the sciences; they are in this sense *transdisciplinary*. The question, then, is within which scientific context can they be appropriately transformed into problems internal to science. The debate concerning transdisciplinarity has made it clear that the conceptual and methodological framework available within both individual disciplines or several disciplines together is insufficient to answer this question. Alone the fact that transdisciplinary research includes various social actors in individual phases of the research process, thereby changing the communicative and intellectual context in noticeable ways, makes this obvious.

If transdisciplinary research doesn't want to lose itself in its contexts of application then it must develop a functional equivalent to theoretically structured discipline based knowledge. One way to meet this problem would be to begin by developing a *theoretical programmatic* encompassing the different disciplines instead of developing a transdisciplinary theory as such. For example, one could develop such a theoretical programmatic in terms of socio-ecological transformations. The new federal funding program for Social-Ecological Research in Germany is an attempt at such a programmatic reorientation of the environmental sciences.

What it is clear, however, is that empirically warranted and theoretically organized knowledge is indispensable for both the transformation of agency problems of everyday life into scientific problems and for the transformation of scientific knowledge into useful methods of problem solving. Equally clear is that one needs specific methods for achieving this. In the last decade the methodology of transdisciplinarity has been improved by many innovations which have occurred for the most part at the operative level. These innovations in method are less in the direction of linear step-by-step approaches and more in the direction of heuristic search strategies for possible problem solutions. Here we find techniques such as the case study method, life cycle assessment, need-field approach and life-style analysis What remains unclear, however, is the *location of the theory*. The disciplines and other specialist cultures have in many cases proven to be the wrong place for such theory construction. Transdisciplinary theory construction, in short, is to a great extent homeless.

The model of transformation roughly sketched here portrays discipline based science in a rather simple way, for the portrait is meant to serve as a contrast to transdisciplinary science, thus helping us to understand the latter better. In research, the task is to transform non-knowledge into knowledge, or, put differently, inner-scientific problems need be solved. To this end, science has developed specific methods as instruments for solving its own problems.

Science, to repeat, is method governed acquisition of knowledge. It is the methods that science employs that make it possible in the first place to bring science into the form of a process, to give it a dynamic movement. Only with the construction of specific methods did the innovation capability of science become possible. But methods also have conserving functions: instruments are calibrated and are not to change during their use; and experiments must be repeatable. Methodological ideals and techniques of formalization are often more defining of the structure of a discipline than either its theories or the objects of these theories. The rigor of modern science is above all a methodological rigor. During the transformation of a complex web of problems, methods and knowledge, now one, now the other element comes into play, depending on the given phase of the scientific process. Research problems are the dynamic element within science; they are the object of its activities, and they structure, to a certain extent auto-catalytically, the scientific process as a problem resolving process.

Within a discipline differentiated system of the sciences problem resolving processes take place primarily within a disciplinary matrix. Moreover, in the field of transdisciplinary research for sustainability, there are at best heterogeneous approaches to theory construction, all of which are far from being completed. Yet even in this undeveloped state of theory construction it is clear that, within the cognitive framework of a transdisciplinary theory, scientific problems arise that are different than those found in a discipline. It is possible that societal problems of a more intransigent nature, those that block any systematic reduction to a form adequate to discipline based investigation and which are thus overlooked by the system of discipline based knowledge altogether, can be reformulated within the framework of a transdisciplinary theory into a form that is open to scientific processing. Such intransigent problems need not arise; but their acknowledged existence – in particular in the area of ecology – provides transdisciplinary theoretical conceptions (systems theory, for example) with a strong legitimation.

If one understands transdisciplinary research, however, as being a genuine scientific activity then it is confronted with theoretical challenges. Already the first level of the process of problem resolution, namely, the transformation of a societal problem into a scientific one, implies at least the sketch of a transdisciplinary cognitive framework. Any problem would be an interdisciplinary or a transdisciplinary one in this sense if it were situated between or beyond the disciplines, while still forming a scientific problem for each of them – or if it could be translated into such a scientific problem. The problem resolution, however, would be transdisciplinary whenever it cannot be covered by any discipline based theory. For that reason transdisciplinary research aims not only at resolving problems within the contexts of application in everyday life but also at constructing transdisciplinary theories – at least so long as one holds on to the scientific ideal of classical modernity as opposed to post-modern patchwork-thinking.

The most intransigent problems within the discipline based system of the sciences lie in the deep gap, constitutive of classical modernity, between the separate spheres of nature and society. Here we find hybrid objects (such as holes in the ozone and acid rain) in which ecological effects and societal interpretation mingle. And here one rarely finds interactions between the two spheres that can be taken as the objects of disciplinary study. For example, the strong mutual influence of natural and social systems is something that is capable of being modeled in a technical manner only with great difficulty.

These interactions can provoke a dynamic process leading to crises that are scarcely confinable, and they constitute something like an anomaly – in the Kuhnian sense – for a discipline based system of the sciences; that is, challenges that refuse to go away and that can only be overcome by means of a paradigm change. Scientific activities that concentrate on such anomalies are per se transdisciplinary, but now in a special sense: they have to combine natural and social scientific methods and knowledge and integrate these in a transdisciplinary manner. If all the talk about the necessity of a fundamental change in the cognitive structure of modern science is to have any sense at all, then it will be in enabling a new framework for working on such anomalies.

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