Chapter 2
The Emergence of Transdisciplinarity as a Form of Research

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Abstract The birth of science is based on a strict dissociation of scientific knowledge from the various aspects of practical knowledge. The ideal of scientific knowledge as it was shaped in antiquity is still influential today, although the conception of science and the relationship between science and the life-world has undergone major changes. The emergence of transdisciplinary orientations in the knowledge society at the end of the 20th century is the most recent step. The Handbook focuses on transdisciplinarity as a form of research that is driven by the need to solve problems of the life-world. Differences between basic, applied and transdisciplinary research, as specific forms of research, stem from whether and how different scientific disciplines, and actors in the life-world, are involved in problem identification and problem structuring, thus determining how research questions relate to problem fields in the life-world. However, by transgressing disciplinary paradigms and surpassing the practical problems of single actors, transdisciplinary research is challenged by the following requirements: to grasp the complexity of the problems, to take into account the diversity of scientific and societal views of the problems, to link abstract and case specific knowledge, and to constitute knowledge with a focus on problem-solving for what is perceived to be the common good. Transdisciplinary research relates to three types of knowledge: systems knowledge, target knowledge and transformation knowledge, and reflects their mutual dependencies in the research process. One way to meet the transdisciplinary requirements in dealing with research problems is to design the phases of the research process in a recurrent order. Research that addresses problems in the life-world comprises the phase of problem identification and problem structuring, the phase of problem investigation and the phase of bringing results to fruition. In transdisciplinary research, the order of the phases and the amount of resources dedicated to each phase depend on the kind of problem under investigation and on the state of knowledge.

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2.1 Science and Life-world: From Dissociation to Transdisciplinary Orientations in the Knowledge Society

At the cradle of science in Greek antiquity the idea evolved that science is basically a cognitive faculty for explaining the development of natural things, including humans. Scientific explanations must be based on principles inherent to natural things, which Aristotle (384–322 BCE) saw as their universal unchangeable form. Aristotle claimed that humans are capable of capturing these evident first principles in 'contemplation', which is the meaning of the Greek term 'theoria'. In antiquity, 'theory' meant the knowledge about self-evident principles on which scientific demonstration is based. This kind of scientific knowledge (*epistême*) is of no use for day to day living. To lead their life, humans need skills to act (*praxis*) and to produce (*poiêsis*), and they need prudence (*phronêsis*) to deliberate about things that allow choice. So, the birth of science is based on a strict dissociation of scientific knowledge from the various aspects of practical knowledge (Aristotle, 2003).

The distinction between scientific and practical knowledge gives rise to the ideal that scientific knowledge is universal, explanatory, demonstrated to be true by a standard method, teachable and learnable. As a consequence, science has to be detached from practical life or the life-world. The term 'life-world' is used for what the phenomenologist Edmund Husserl (1859–1938) called 'Lebenswelt' – meaning the ongoing lived experiences, activities and contacts that make up the world of an individual or corporate life. Alfred Schütz (1899–1959) introduced the term into sociology to describe the structural properties of social reality as grasped by the agent – the agent's life-world (Schütz and Luckmann, 1973). Jürgen Mittelstraß uses the term in defining 'transdisciplinarity' as a form of research that transcends disciplinary boundaries to address and solve problems related to the life-world (Mittelstraß, 1992).

The ideal of scientific knowledge as it was shaped in antiquity is still influential today, although the conception of science and the relationship between science and the life-world has undergone major changes. Important transformations have taken place. The enlightenment started with the dissociation of the natural sciences from philosophy, followed in the 19th century by the establishment of the humanities and the social sciences as separate specialised disciplines in universities. The emergence of transdisciplinary orientations in the knowledge society at the end of the 20th century is the most recent step in reshaping the conception of science and the distinctions between science and the life-world.

The conception of science in the modern period is shaped by the dissociation of the natural sciences from philosophy. The foundations of theory oriented experimental interventions into nature were in place by the end of the 16th century. Modern natural science retains the idea that scientific knowledge is about general principles that explain processes in nature. However, these principles are conceived as causal laws in the sense of abstract idealised models that relate events in time and space as causes and effects, and explain the variation of events due to those causal influences. These laws are tested by experimental research, by intervening in nature under standardised laboratory settings. Consequently, while theories are still elaborated by deductive ordering, statistical methods are now used to prove that a theory holds true in a general way for processes of a certain kind, replacing antiquity's demonstration by deductive reasoning from self-evident first principles. Newtonian mechanics, which reduces the plurality of phenomena in nature to some basic laws, is the leading example of the modern conception of science.

Interestingly, a paradigm for conceiving the complexity in science emerges as early as the 18th century. Johann Heinrich Lambert (1728–1777) developed a systems approach to structure complexity as a set of interrelated elements. Lambert described various types of systems such as systems of scientific knowledge, belief systems of cultures, religions and narratives, including systems that are constructed to realise desired states. The latter systems are formed by uniting objectives and means, the parts of which are correlated on the basis of natural causalities and voluntary decisions. Thus human agency becomes a subject of scientific knowledge. Lambert was a distinguished mathematician, philosopher and natural scientist in his own time: although his 'systematology' received little attention it became an early forerunner of present day systems thinking (Rescher, 1979).

Newtonian science is also closely related to practical issues such as the production of goods. Science in the modern period is concerned with empirical laws and is carried out as research by intervening into nature in technically equipped experimental settings. The close relations between modern science and technology open ways for science based technological innovation, which can be used in industry for the production of commercial goods. The benefit to society of progress in science and technology is the core argument of Francis Bacon (1561–1626) in his 'novum organum' for a new science in the early 17th century (Bacon, 2000). Bacon was convinced that collaboration among scientists is most important for scientific progress, which is for the sake of societal benefit. This idea was important in the founding of the *Royal Society* in 1662. With the rise of the liberal market economy in the 19th century the use of knowledge from natural sciences and technology in industrial production began to play a major role in welfare economics. The instrumental interest in scientific knowledge from economics and society became an external driving force for the investment of resources in the progress of modern science and its experimental, quantitative and mathematical perfection. The purpose of improving the standard of living by improved quality, and increasing quantities of goods has been uncontested in society for a long time. As a result, many see scientific activity as free from extra-scientific societal values. Such an understanding does not take into account the way modern science and technology is imbedded in economic activities, cultural orientations and political measures or how these shape and legitimate scientific development as external drivers. Awareness of the way science is embedded in extra-scientific values and institutions has grown with the various steps in the debate about the modern conception of science and the role of science in the life-world.

In the 19th century, the conception of modern science was criticised as a model for all of science. When the humanities and history dissociated from philosophy the model of science that explained events by universal causal laws based on experimental testing for their fields was reflected. Wilhelm Dilthey (1833–1911) advocated a hermeneutic paradigm to achieve an understanding of cultural ideals and historical configurations, which constituted the identity of a cultural epoch in the history of mankind. He conceived of the humanities as hermeneutic sciences that rely on a method of understanding the meaning of life by interpreting its expressions in texts and other symbols. Wilhelm Windelband (1848–1915) also saw the methods and subjects of history as distinct from those of the natural sciences (Chapter 24). In his famous inaugural address as rector of Strassburg University in 1894 he argued that the natural sciences explain general aspects of empirical events by universal laws, while history investigates the individuality of empirical phenomena, giving them values to aid the understanding of their meaning and importance.

The methodological division within the sciences continued with the development of the social sciences. The emergence of the social sciences during the 19th and first half of the 20th century was influenced by the serious problems experienced by the country workers and the industrial working class due to major economic, social and political transformations. The destructive influence of colonialism in the south got little attention at that time. However, the social risks of industrialisation and migration in the north attracted attention and stimulated innovative developments in academia, for example, in the 1920s, the Chicago School of Sociology in the United States, and also shaped Human Ecology (Groß, 2004). In Europe developments began earlier with Karl Marx (1818–1883), Max Weber (1864–1920) and Emile Durkheim (1858–1917), whose thoughts were taken up by Talcott Parsons (1902–1979) in his seminal theoretical work 'The Structure of Social Action' (Parsons, 1968). Max Weber related research in social sciences with knowledge demands for societal problem-solving. For him, the stimuli behind the posing of scientific problems were always practical problems, which thus coincided with specifically oriented motives and values (Weber, 1949). He started with empirical investigations of social problems in Germany and made major theoretical contributions to the rise and shaping of sociology as a science of societal agency with his conception of ideal-types for understanding societal institutions. Ideal-types structure institutions and agencies analytically, and thus organise their complexity as value oriented complex functional wholes. Weber was well aware of the individual complexity of concrete settings. He therefore called his general analytical schemes ideal-types. Ideal-types are theoretical idealisations in the sense that they are grounded rational constructs of societal institutions and agencies. They are useful in describing and analysing empirical phenomena to the degree that they approximate empirical cases. The degree by which an ideal-type diverges from empirical observations indicates whether another ideal-type needs to be developed for understanding these phenomena (Weber, 1949).

Since then, actions of individuals and institutions have been a prominent subject for investigation in the social sciences, giving rise, in the 20th century, to a long-lasting debate about the conception of the empirical sciences and their relation to societal values (Chapter 23). The beginning of the debate is labelled 'Werturteilsstreit'. Starting from a clear cut distinction between facts and values, proponents of a 'neutrality of science in societal value issues' like Weber, argue that empirical sciences are about what is either true or false, while the normative distinction in the sphere of values is that of right or wrong. Weber rejected the possibility of an ethical foundation for value judgments, and restricted the tasks of empirical science to the analysis of the rationality of societal forms of agency as a means to certain ends, while pointing out that negative side-effects of behaviour should be involved in judging its rationality (Weber, 1949).

According to this view the benefit of the social sciences for practical life is – analogous to the natural sciences – an instrumental one. In this case, this is beneficial for structuring and regulating the effectiveness and efficiency of human agency. Since then the controversial debate within the social sciences and philosophy is about whether scientific investigation is restricted to the instrumental rationality of knowledge. Subsequently, the position of Sir Karl Popper (1902–1994) and Hans Albert (born 1921) in the 1960s has been to restrict scientific investigation of extra-scientific values to the functional analysis of means to certain ends. Jürgen Habermas (born 1929) in his critique of positivism in 'Knowledge and Human Interest' argues for three types of scientific rationality related to specific standards in research (Habermas, 1968): (1) the instrumental rationality of the empirical sciences and their standards of quantification and experimental testing, (2) the rationality of the historical sciences, which concerns the role of knowledge in creating meaning for life and constituting personal identity in societal contexts, based on rules for hermeneutic interpretation, and (3) the sciences of action, which are about societal transformations (in his later works this is based on communicative rationality as communicative action). According to this conception participants engage in deliberation, following the regulative percept of an 'ideal speech-situation' (Habermas, 1984, 1987). In transdisciplinary research, Habermas' conception of communicative rationality is broadly referred to, providing foundations for models of dialogue and knowledge claims (Chapter 21). This typology of the sciences and their rationality replaces the strict distinction in antiquity of science as *epistême*, on the one hand, and the knowledge of the life-world as *poiêsis, praxis* and *phronêsis*, on the other hand, by relating different conceptions of science with different types of interests: production, action and deliberation.

Of major importance for transdisciplinary research is a further alternative to the positivist view and its ideal of a physicalistic unitary science, namely the development, beginning in the 1940s, of systems theory in a broad range of fields. Systems theory was proposed by Ludwig von Bertalanffy (1901–1972) in biology; and developed by Norbert Wiener (1894–1964) in cybernetics; by John von Neumann (1903–1957) in game theory; by Claude Elwood Shannon (1916–2001) in information theory; and by Niklas Luhmann (1927–1998) in sociology, to mention some eminent individuals. Systems theory studies the abstract organisation of phenomena, independent of their substance, type, or spatial or temporal scale of existence. It investigates both the principles and the mathematical models used to describe them. These developments give rise to the idea of an abstract structural unity of scientific knowledge against the background of the progressive fragmentation of the sciences into more and more specialised disciplines and thematic fields. The continuing differentiation in research and higher education, as well as in social institutions in general, becomes a major risk for modern civilisation, because specialisation prevents the recognition of possible negative side effects. Multidisciplinary research approaches an issue from the perceptions of a range of disciplines; but each discipline works in a self-contained manner with little cross-fertilisation among disciplines, or synergy in the outcomes. The growing awareness of these kinds of risks therefore stimulates integrative approaches labelled 'interdisciplinarity' or 'transdisciplinarity'. It is in this context that Erich Jantsch (1929–1980) an others argued for innovations in planning for society at large, in a government–industry–university triangle which included a far-reaching reorganisation of higher education into an education–innovation system. He proposed that knowledge should be organised into hierarchical goal oriented systems. Blueprints for such coordinated frameworks, for which he introduced the term transdisciplinarity, would be general systems theory and organisation theory; that is, the study of organisations by the means of systems theory. He distinguished four levels within such a system: 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). Values were crucial to his transdisciplinary systems because this approach involved activities at all levels of the education–innovation system being coordinated towards a common purpose (Jantsch, 1972).

Joseph Kockelmans (born 1923) argues against restricting problem oriented research to theoretical frameworks. This is in the spirit of general systems theory or structuralism, proposed by Jean Piaget (1896–1980) to address the unity of the sciences against the background of fragmentation of knowledge. Kockelmans suggests the term 'crossdisciplinary work' for research which 'is primarily concerned with finding a reasonable solution for the problems that are so investigated, whereas transdisciplinary work is concerned primarily with the development of an overarching framework from which the selected problems and other similar problems should be approached' (Kockelmans, 1979). From this, it becomes clear that there are several quite different cognitive motives for transcending boundaries between disciplines, such as unity of knowledge in general, grasping the complexity of concrete issues, and innovation in basic research as, for instance, in the case of molecular biology. On the other hand, a variety of terms such as interdisciplinarity, crossdisciplinarity, transdisciplinarity and others have been coined to distinguish between the forms and functions of crossing disciplinary boundaries. Unfortunately these terms do not always have the same meaning, due to independent developments and different related motives.

While these emerging ideas about inter-, cross- and transdisciplinarity are widely discussed with comparatively little impact on research or on institutional structures in universities, systems analysis and modelling are advancing to become leading paradigms in the natural and social sciences. They are used for describing complexity and for analysing 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; Chapter 3). It is in this context, that in 1986 Ulrich Beck coined the term 'Risk Society' (Beck, 1992). In his bestseller he points at the radical transformations in so much of everyday life in the industrial society, together with unintended and poorly understood damage to natural resources and life-support systems. As a consequence he sees the sciences becoming reflective, meaning that they will become increasingly busy understanding and handling the negative side-effects of the use of science based technological innovations in society. Beck insists that these effects have to be understood as hybrids that no longer match the separation of natural events and societal meaning. Modernisation itself induces hazards and insecurities, which call for precautionary and systematic ways of dealing with hazards as essentially political issues. Social sciences and humanities become involved in activities such as technology assessment, ethical committees on morally sensitive technologies as well as research into the ethical, legal and social implications (ELSI) of technologies (Chapter 9 and Chapter 10) such as ELSI research within the Human Genome Program. According to Beck, society and the sciences undergo intertwined transformations into a risk society in 'Science beyond Truth and Enlightenment' (Beck, 1992).

Beck is criticised for his rather vague statements about the transformations of science. Silvio Funtowicz and Jerome Ravetz clear some of these grounds with their conception of post-normal science (Funtowicz and Ravetz, 1993; Chapter 23), which has been the result of their analysis of the management of high uncertainty and decision stakes in policy related scientific inquiries. They find that the paradigm of normal science is inadequate to ensure the validity of knowledge about these kinds of issues. Therefore routine scientific expertise is inadequate and professional knowledge and judgment are insufficient to address these policy issues. They argue that in such cases science must engage in dialogue with all those who have a stake in the decision. Quality assurance of scientific inputs to the policy process is perceived as mutual learning, with stakeholders as an extended peer community. While science is becoming an agent in the policy process, ideas about reflectivity and democratisation of science attract broad attention, especially within the community of science and technology studies (STS). These ideas undergo various interpretations and adaptations. In 1994 Michael Gibbons and his colleagues published their 'New Production of Knowledge', in which they contrasted Mode 1 of knowledge production, the Newtonian model, with a Mode 2, emerging in the field of research and development, which has features such as transdisciplinarity, heterogeneity, reflectivity, social accountability, and context- and user-dependency (Gibbons et al., 1994).

Through scientists entering into dialogue and mutual learning with societal stakeholders, science becomes part of societal processes, contributing explicit and negotiable values and norms in society and science, and attributing meaning to knowledge for societal problem-solving. Within such hermeneutic frameworks problem-solving includes reflection, the transformation of attitudes, the development of personal competences and ownership, along with capacity building, institutional transformations and technology development. Mutual learning connects transdisciplinary orientations to action research, a conception aimed at mutual benefit to theory and practice. Action research is driven by three principles: (1) The location of the starting point in social reality, i.e. people's interpretation of reality. Action research, therefore, is related to interpretative approaches of social research, which extend back to the Chicago school of sociology of the 1920s. (2) Action in field research, aimed at learning about the consequences of different forms of social action. Research directed toward the solving of social problems was developed by Kurt Lewin (1890–1947). To achieve this, action, research and education must form an interlinked triangle (Lewin, 1951). (3) The so-called subject status of the research object or participation. Jakob L. Moreno (1889–1974), proposed that researchers and the people studied should both research and be researched, and both should participate in the situation and intervene to create change in accordance with their competences. Action research was adopted in studies about religious and racial prejudices and in projects concerning education and social work during the social upheaval of the 1960s and 1970s. Thanks to the work of Chris Argyris and Donald Schön on experiential and organisational learning, as well as on theories of action (Argyris and Schön, 1996), action research has found its way into transdisciplinary projects concerned with sustainable development of companies, landscape research and Local Agenda 21, to note a few examples.

During the past thirty years similar changes have been taking place in the design of research projects in development cooperation. Where, at the beginning, researchers defined the problems and the solution, now, the affected population's participation is supported in the research process. Experience shows that without participation, the resulting measures and outcomes are likely to be rejected or ignored by the local population. New approaches and methods, such as rapid rural appraisal (RRA) and participatory rural appraisal (PRA), are being developed. In addition to integrating the local population into the research process in an active way, the diversity and complexity of social, political, economic and environmental problems has to be adequately met (Chapter 3, Chapter 4 and Chapter 17). 'Diversity' means that empirical dimensions relevant to describing and analysing processes are heterogeneous in the sense that they belong to different disciplines or to the perceptions of different actors, and that there are plural values and norms that do not fit together in a systematic way. Diversity of dimensions or values is in contrast to homogeneity with respect to the disciplines and life-world perceptions involved. 'Complexity' is used for the interrelations among heterogeneous dimensions, or plural values and norms. Thus complexity is in contrast to simplicity.

Against the background of the perceived diversity and complexity of development problems and trends it becomes obvious that the formerly dominant set of theories – modernisation and dependency theories in the social sciences – have only limited explanatory power. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992 had the commitment of the statesmen from most nations to sustainable development. It marked a paradigm shift in thinking about developmental issues. Sustainable development is a global socio-political model for changing practices and institutions in order to achieve more equitable opportunities within and between generations while taking into account the limitations imposed by the state of technology and social organisation on the environment's ability to meet present and future needs (World Commission on Environment and Development, 1990). Promoting sustainable development therefore necessitates overcoming narrow preoccupations and compartementalised concerns by involving people from civil society, the private sector and public agencies as actors in participatory deliberation and decision making. Thus sustainable development is a way to conceive the common good as the basic principle of public legislation in a complex world. Agenda 21, a UN program, is a comprehensive blueprint for action to be taken globally, nationally and locally.

The Rio Conference and The World Summit on Sustainable Development held in Johannesburg in 2002 were highlighting the importance of science to sustainable development, and stressing the need to transform research by involving stakeholders and promoting mutual learning between science and the life-world (Hirsch Hadorn et al., 2006). When a group of authors in the 1970s first published 'Finalization in Science: The Social Orientation of Scientific Progress' (Böhme et al., 1983), in which they showed how the external orientation of scientific development was becoming more and more important for the development of the sciences, compared to putting forward endless internal scientific frontiers, the scientific world was shocked. The conception of science in the analysis of finalization is still that of scientific disciplines. These disciplines are now being responsive to problems in the life-world, which are external to their cognitive domain. Therefore, a problem oriented restructuring of knowledge was needed to produce knowledge that was valid for specialist problem-solving and translatable into technological innovation. In today's knowledge society, with sustainable development as its normative model, even forms of research and the role of science in societal change are altering. Science is not only a resource, but an 'agent of change' (Krohn and van den Daele, 1998): society is not only integrating scientific knowledge but adopting scientific research for societal problem-solving and innovation.

It is this bigger picture of ongoing and intertwined transformations in academia and the life-world during the modern period, especially in the last 30 years, which has to be kept in mind when looking at the challenges of, and opportunities for, transdisciplinary research. From this historical perspective it becomes clear why transdisciplinary research is a fuzzy and contested field, shaped by various lines of thinking, heterogeneous conceptions of science and approaches to research, with a variety of terminologies and definitions. The next section will comment on some of these and propose a structure as guidance for readers.

2.2 Transdisciplinarity as a Form of Research

Disciplines shape scientific research by forming the primary institutional and cognitive units in academia, on which the internal differentiation of science into specialised curricula, professions and research, is based (Stichweh, 1992). Members of a discipline are specialists who build a scientific community (Kuhn, 1963). Members communicate within their community, share basic assumptions and examples about meaningful problems, standards for reliable and valid methods, as well as what is considered a good solution to a problem. What modern science gains and preserves is based to a large extend on disciplinary structures. However, boundaries between disciplines are changing: by increasing specialisation through internal differentiation within the disciplines, and by the integration of disciplines.

One intellectual motive for transgressing disciplinary boundaries and integrating different disciplinary perspectives has been the search for innovation in fundamental scientific understanding of specific problems, often linked with innovation in investigative methods. Among the many examples are developments in the social sciences (Sherif and Sherif, 1969), in biology (Bechtel, 1986) and recently in the field of nanotechnology and nanoscience. Endeavours of this kind, which are motivated by factors internal to the scientific knowledge system, are often termed 'interdisciplinarity'. Migration and collaboration by researchers between disciplines, which take place in such interdisciplinary endeavours, change the landscape of disciplines by the transformation of existing disciplines, and the emergence of new ones.

A second motive stems from the knowledge demands of the knowledge society. Societal knowledge demands for a better understanding of, and solutions to, concrete issues in the life-world, function as an external driver for transgressing disciplinary boundaries and integrating different disciplinary perspectives. Although this is a different kind of endeavour, it is sometimes also called 'interdisciplinarity', as for instance in the following definition:

> Interdisciplinary research (IDR) is a mode of research by teams of individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond of the scope of a single discipline or area of research practice. (National Academies, 2005)

It is helpful to make a terminological distinction between these two different endeavours. One suggestion is to specifiy interdisciplinarity in the context of knowledge demands in the life-world with the help of additional terms such as 'interdisciplinary problem-solving' (Clark, 1999; Deppert, 1998) or 'goal oriented interdisciplinarity' (Hubert and Bonnemaire, 2000); or defining them as 'Mode 1 interdisciplinarity' and 'Mode 2 interdisciplinarity' (Bruce et al., 2004). It is, however, more useful to use a different term, such as the term 'transdisciplinarity' (Jantsch, 1972) as we do in the 'Handbook of Transdisciplinary Research'. Various more or less radical views of the transformation of science involving the transgression of disciplinary boundaries in addressing issues in the life-world in research, have emerged. These have resulted in the coining of specific terms such as 'post-normal science' (Funtowicz and Ravetz, 1993), 'Mode 2 of knowledge production' (Gibbons et al., 1994), and 'policy science' (Clark, 2002).

Jürgen Mittelstraß (1992) argues that transdisciplinarity is primarily a form of research for addressing and reflecting on issues in the life-world. Against the background of harm and serious risk posed by technologies and growth that does not fit within the disciplinary paradigms of academia, he calls for the transgression of disciplinary boundaries for identifying, structuring and analysing problems in research. Contrary to the more pragmatic approach of transdisciplinarity as a form of research, others argue for a further intellectual endeavour on a fundamental theoretical level. They conceive of transdisciplinarity as a theoretical unity of all of our knowledge, which they think is needed to respond adequately to knowledge demands for problem-solving in the life-world. (Nicolescu, 1996; Max-Neef, 2005). In coining the term 'transdisciplinarity' in 1972, Erich Jantsch envisioned a systems theory approach for the purpose oriented integration of knowledge to grasp the complexity of problems in the life-world:

> Transdisciplinarity: The co-ordination of all disciplines and interdisciplines in the education/innovation system on the basis of a generalized axiomatics (introduced from the purposive level) and an emerging epistemological ("synepistemic") pattern. (Jantsch, 1972)

Systems theory has been influential in shaping a range of transdisciplinary schools, among them 'human ecology' (Ehrlich et al., 1973), the 'Man and Biosphere' research concept (Chapter 3), 'ecological economics' (Costanza et al., 1997), 'sustainability science' (Kates et al., 2001) and 'socio-ecological research' (Becker and Jahn, 2006; Chapter 6).

Scholars in Social Studies of Science (STS) investigate the transformation of knowledge production in applied and policy oriented research, as opposed to basic research. Among other features, they stress the need for the participation of stakeholders in the research process (Chapter 22). Because of the high level of uncertainty of knowledge and the high decision stakes involved, Funtowicz and Ravetz in their conception of 'post-normal science' argue for mutual learning between scientists and stakeholders with stakeholders belonging to an 'extended peer community', and for quality control of knowledge in policy oriented research (Funtowicz and Ravetz, 1993; Chapter 23). In the context of application, Gibbons and colleagues in their 'Mode 2 of knowledge production' (Gibbons et al., 1994) insist on mutual learning for 'socially robust knowledge' (Nowotny, 1999). The collaboration of both researchers and actors in the life-world can be found in many definitions of 'transdisciplinarity'. This is highlighted by Julie Klein's definition:

> The core idea of transdiscipinarity is different academic disciplines working jointly with practitioners to solve a real-world problem. It can be applied in a great variety of fields. (Klein et al., 2001)

In summary, there are about four core concerns which show up in definitions of 'transdisciplinarity' or related terms: first the focus on life-world problems; second the transcending and integrating of disciplinary paradigms; third participatory research; and fourth the search for unity of knowledge beyond disciplines. While the first two concerns are widely shared, there is disagreement over whether, and to what extent participatory research is needed for taking into account societal views in investigation issues. There is even more disagreement about the importance of the search for unity of knowledge in addressing issues in the life-world.

The 'Handbook of Transdisciplinary Research' focuses on transdisciplinarity as a form of research that is driven by the need to solve problems of the life-world. To cover a broad range of research experiences and bring it to fruition in the 'Handbook of Transdisciplinary Research' a broad conception of 'transdisciplinary research' is used. This conception is developed and explained in more detail in td-net's 'Principles for Designing Transdisciplinary Research' (Pohl and Hirsch Hadorn, 2007). Based on a synthesis of what can be found in the literature the conception refers to cognitive features of the starting point, the requirements and the goals of a transdisciplinary research process:

> There is a need for TR when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them. TR deals with problem fields in such a way that it can: a) grasp the complexity of problems, b) take into account the diversity of life-world and scientific perceptions of problems, c) link abstract and case specific knowledge, and d) constitute knowledge and practices that promote what is perceived to be the common good. (Pohl and Hirsch Hadorn, 2007)

Features of the starting point, namely high uncertainty of knowledge and high decision stakes are at the core of post-normal science (Funtowicz and Ravetz, 1993). Furthermore, grasping the complexity of the problems, taking into account the diversity of life-world and scientific perceptions of problems, as well as linking abstract and case specific knowledge, are widely shared concerns in transdisciplinary research processes. However, the goal, which is to constitute knowledge and practices that promote what is perceived to be the common good, is seldom explicitly stated in a definition, although it is sometimes implied, for instance by the term sustainability science (Kates et al., 2001). An exception is policy science (Clark, 2002), which explicitly refers to the common interest as the normative principle for assessing problem-solving measures.

Transdisciplinary research relates to three types of knowledge: systems knowledge, target knowledge and transformation knowledge. The terms are coined in 'Research on Sustainability and Global Change – Visions in Science Policy by Swiss Researchers' (ProClim, 1997). The definition of 'systems knowledge' as knowledge of the current status; of 'target knowledge' as knowledge about a target status; and 'transformation knowledge' as knowledge about how to make the transition from the current to the target status (ProClim, 1997); however, can be open to a technocratic misunderstanding. Therefore these forms of knowledge are described by the types of questions to be addressed by transdisciplinary research (Pohl and Hirsch Hadorn, 2007):

- Questions concerning the genesis, further development and interpretation of a problem in the life-world are answered by systems knowledge of empirical processes and interactions of factors – including the interpretations given to these in the life-world.
- Questions related to determining and explaining the need for change, desired goals and better practices that call for target knowledge.
- Questions about technical, social, legal, cultural and other possible means of acting that aim to transform existing practices and introduce desired ones, which have to be answered by transformation knowledge.

There are similar distinctions between forms of knowledge using different terminologies by other authors (Becker et al., 1999; Deppert, 1998; Costanza et al., 1997; Jantsch, 1972).

These three forms of knowledge remind us of Aristotle's forms of knowledge, namely: science (*episteme*); life-world action (*praxis*); production (*poiêsis*); and prudence (*phronêsis*) – now transformed as goals of transdisciplinary research. Being goals of transdisciplinary research means that the investigation of each of the three types of questions requires that explicit assumptions with regard to the other two types are made. Thus, instead of being investigated in isolation, research questions that refer to target knowledge should be examined on the basis of specific assumptions about systems relations and with a view to finding out about specific options for transforming existing practices. The opposite is also important: an empirical analysis of systemic relations must refer to the transformation of a specific social practice with a specific objective in mind; and studies of possible change options need to be based on specific knowledge about systems relations and goal oriented practices. Furthermore, instead of being conceived of in a sequential order as in the classical technical model of problem-solving, these three forms of knowledge form a triangle reflecting the mutual dependencies (Fig. 2.1).

This integrative perspective of the three forms of knowledge also displays an important difference to Habermas' conception of the different types of scientific rationality. This becomes clear when looking at the particular challenges that each form of knowledge has to face to produce valid knowledge. Systems knowledge needs strategies for dealing with uncertainties. On the one hand, these uncertainties are the result of transferring abstract insights from a laboratory, model or theory to a concrete case underlying specific conditions. On the other hand, depending on the

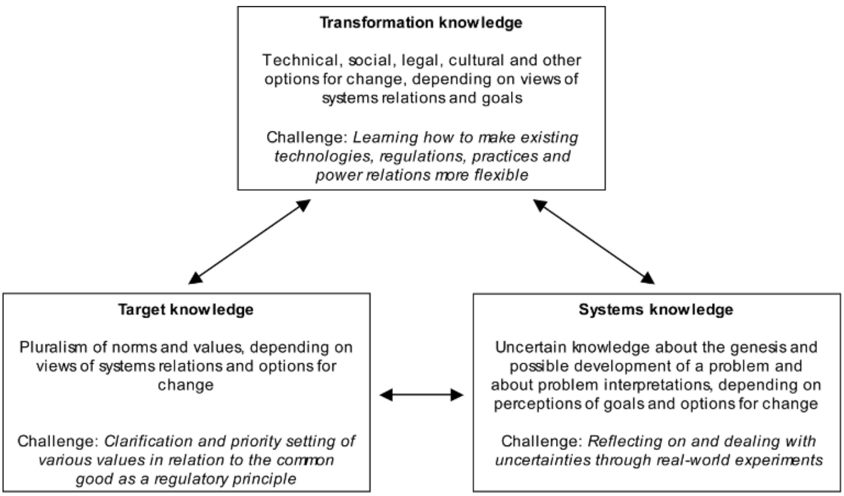

Fig. 2.1 Interdependencies between systems, target and transformation knowledge and their particular challenges (Pohl and Hirsch Hadorn 2007, p. 38), adapted

approach to and interpretation of the problem, these uncertainties may be attributed different degrees of importance, leading to different assessments of targets and of transformation knowledge. In the case of target knowledge, against the background of multiple interests, needs and attitudes of stakeholders, a standard is needed to clarify the variety of positions, and to guide deliberation about their significance for problem-solving. This is the role of referring to and interpreting the common good, or more specifically, the sustainability model in addressing target and transformation knowledge. In the case of transformation knowledge, when designing technical, social, legal, cultural and other options, the challenge is to learn about the flexibility of existing infrastructure, current laws, and to a certain degree about current power relations, cultural opinions and people's capabilities for learning (Argyris and Schön, 1996). It is necessary to learn to make what is existing more flexible in order to have any chance of successfully navigating between 'the Scylla of political irrelevance and the Charybdis of technical inadequacy' (Guston and Sarewitz, 2002).

The starting point, requirements and goals of transdisciplinary research have major implications for the way problems and research questions must be identified and structured. To understand these challenges a comparison of transdisciplinary, applied and basic research is helpful. For this purpose, we conceive of basic, applied and transdisciplinary research as three ideal-types, thus doing justice to the fact that projects have characteristics of certain forms of research to a higher or lower degree: projects can combine features of different research forms. Differences between basic, applied and transdisciplinary research, as specific forms of research, stem from whether and how scientific disciplines, and actors in the life-world, are involved in problem identification and problem structuring, thus determining how research questions relate to problem fields in the life-world. In Fig. 2.2 each form of research is represented by a three column diagram to show the different ways of determining research questions and how those questions relate to problem fields. In the diagrams, scientific disciplines form the column to the left. The range of disciplines from sciences and humanities is illustrated by economics, ethics, molecular biology, and ecology. Disciplines evolve and change over time by means of internal differentiation as well as by integration. To keep the figure simple, this is not indicated in the diagrams. The right hand column shows actors in the life-world. In this third column the private sector, civil society, and public agencies, are each comprised of a range of institutions acting from local to global scales. To keep the diagrams simple, specific institutions and stakeholders are not included. The private sector, civil society, public agencies and disciplines of sciences and humanities interact as four policy cultures in dealing with policy issues in the knowledge society (Elzinga, 1996). The middle column lists a few examples of problem fields: poverty, land degradation, disease, and hunger. Borders between the problem fields are fuzzy as they build complex clusters with mutual influences and overlaps.

When identifying and structuring problems to determine research questions it is necessary to reduce the diversity and complexity of elements, structures and processes in problem fields by distinguishing between important and irrelevant aspects. Reducing diversity and complexity has to be based on knowledge. In Fig. 2.2, circles indicate the knowledge bases. The way knowledge bases in the sciences and in the

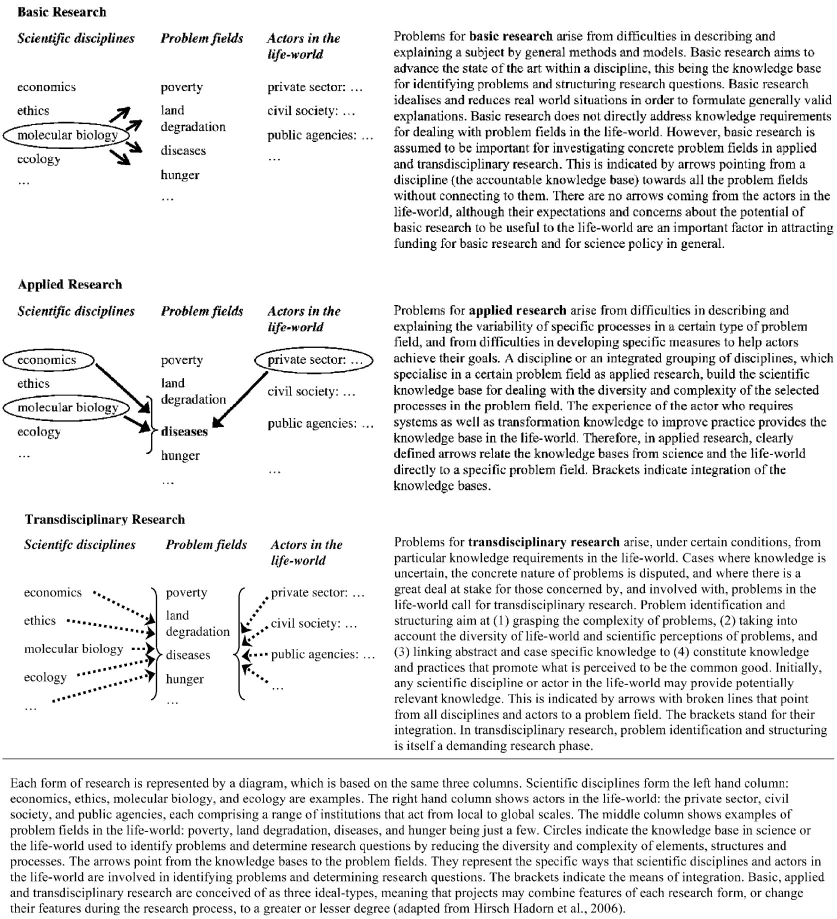

Fig. 2.2 Problem identification and structuring in basic, applied and transdisciplinary research (Hirsch Hadorn et al. 2006, p. 123–124) adapted

life-world are involved in reducing diversity and complexity for problem structuring and determining research questions in relation to problem fields, is different in each form of research. This is indicated by the different arrows that relate the knowledge base involved in determining research questions to the problem fields in each form of research.

Problems for basic research arise from difficulties in explaining and describing a subject by generally valid principles of a discipline. Members of a discipline share examples of good quality problems and solutions, concepts, methods, and standards for research using institutions such as journals, textbooks and educational programmes. These elements constitute the paradigm of a discipline (Kuhn, 1963). A paradigm ensures that research questions can be answered in a valid and reliable way. To arrive at theoretical explanations in basic research, problems must be modelled and investigated under standardised conditions: an idealisation of what happens in real world settings. Therefore, many factors that could contribute to the genesis and development of issues in a problem field have to be ignored. These factors could be a subject for other disciplines, again in an idealised way, but from a different perspective. For example, in the case of biological processes identified as a research problem for molecular biology with assumed relevance for some diseases, researchers will not concern themselves with cultural practices or economic conditions that also contribute to the causes of epidemics or disease. Such factors are a subject for investigation by other disciplines.

As a result, research questions in basic research aim at advancing the state of the art and do not directly address knowledge requirements for dealing with problem fields. It is, however, claimed that explanations of basic research, e.g. in molecular biology, are important for applied research investigations in concrete problem fields such as poverty, disease, land degradation and hunger. Therefore, in the Basic Research section of Fig. 2.2, the arrows that indicate the knowledge base for problem structuring start from one discipline as the only knowledge base. Arrows point towards all problem fields because knowledge of basic research is conceived of as universal knowledge. However, arrows do not connect with problem fields, because basic research does not address the way problems occur in problem fields. That is the task of applied research. For the same reasons, there are no arrows coming from actors in the life-world. Their knowledge, interests and concerns do not directly contribute to problem structuring in basic research, although their expectations and concerns about the potentials of basic research for the life-world have major implications for basic research funding and for science policy in general. The potential of knowledge gained in basic research to improve the approach to problem fields by actors in the life-world is still an issue that needs to be realised in applied and transdisciplinary research.

Applied research describes and explains the variable processes in a certain problem field and develops specific measures and support for the actors concerned. For this purpose the knowledge base in science is built by disciplines specialising in the applied research of a specific problem field. The diversity and complexity of factors in the problem field can trigger the integration of knowledge of further disciplines and development of an interdisciplinary conception of the problem, also called 'Mode 2 interdisciplinarity' (Bruce et al., 2004). Furthermore, the interests and knowledge of the actor, who requires systems knowledge as well as transformation knowledge to improve his practice, are involved in shaping research questions. This is indicated by arrows that relate the relevant knowledge bases from science and the life-world to the problem field. The example in Fig. 2.2 shows molecular biology and economics being applied to investigate a certain disease and develop a drug that can be produced by the pharmaceutical industry. Applied research is often funded by the private sector or by public agencies asking for knowledge in the search for innovation or to improve their dealing with issues in the life-world.

Transdisciplinary research is needed when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by problems and involved in dealing with them. However, by transgressing disciplinary paradigms and by surpassing the practical problems of single actors, transdisciplinary research can no longer build on clearly defined knowledge bases in science and the life-world. As a consequence, research problems that are soluble thanks to disciplinary paradigms of problem structuring and to the restriction of the range of interests taken into account, are turned into issues that scientists and agents can grapple with. The challenges mentioned give a reason for defining transdisciplinary research by the following requirements and goal: to grasp the complexity of the problems, to take into account the diversity of scientific and societal views of the problems, to link abstract and case specific knowledge, and to constitute knowledge with a focus on problem-solving for what is perceived to be the common good.

A way to meet these requirements is to design the phases of the research process in a recurrent order. Problem-solving research comprises the phase of problem identification and problem structuring, the phase of problem investigation and the phase of bringing results to fruition. Traditionally these phases follow a sequential order, with an emphasis on problem investigation. In transdisciplinary research, the order of the phases and the amount of resources dedicated to each phase depend on the kind of problem under investigation and on the state of knowledge (Fig. 2.3).

Problem identification and problem structuring is the phase of the transdisciplinary process in which researchers and actors in the life-world jointly work on identifying and understanding the nature of specific problems in a problem field. Participants are engaged in jointly framing and structuring the fuzzy issues in a problem field with regard to: the genesis and possible further developments of a problem; determining and explaining the need for change, desired goals and better ways of acting; and to technical, social, legal, cultural and other possible means of transforming existing practices. Thus the knowledge demands of systems, target and transformation knowledge are determined. In transdisciplinary research the phase of problem identification and structuring is very resource demanding because it cannot build on a specific knowledge base, as can basic and applied research. Instead, a

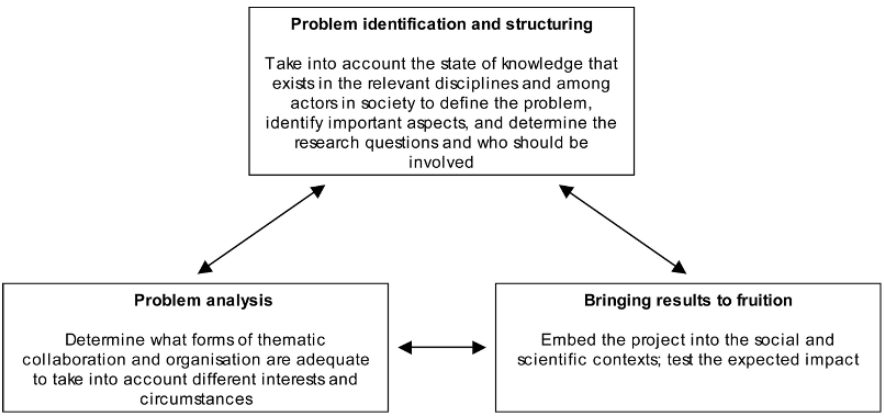

Fig. 2.3 The three phases of research in a transdisplinary research process (Pohl and Hirsch Hadorn, 2007, p. 42)

broad range of participants and competences have to be involved to properly identify the relevant scientific disciplines and actors in the life-world, to evaluate the existing knowledge in academia and the life-world about the problems and to learn about the needs and interests at stake. This information can function as the knowledge base to determine the knowledge available for problem-solving, the questions that need to be addressed in research, and the competences that are required for the investigation and deliberation of results.

Of course one outcome of this phase could be that some knowledge is available and – instead of engaging in deeper investigation – allows the designing and implementing of measures to test the effectiveness of that knowledge to proceed. But this kind of real world experiment (Chapter 24) may lead to surprising results, which call for the investigation or even a restructuring of problems and research questions. Another possible outcome of problem structuring and investigation is that quite different competences and participants may be required in a project than was initially expected. Furthermore, problem identification and structuring, on the one hand, and problem analysis, on the other hand, can overlap. This makes an iterative treatment of phases a more rational approach for achieving valid results, than a sequential treatment.

The requirements and goals of transdisciplinary research also have implications for the phase of problem analysis. In order to grasp the relevant complexity of relations when research questions are structured into more specific ones for detailed analysis, an adequate understanding is needed of the way in which the diverse aspects and perspectives are integrated. In addition, quality assurance of knowledge has to take into account mutual influences between systems knowledge, target knowledge and transformation knowledge. From this it becomes clear that knowledge is related to conceptual, epistemological and methodological uncertainties (Chapter 23).

Furthermore, although research results are expected to be valid for problem-solving in concrete settings, some abstraction in cognitive conceptions is important, otherwise transdisciplinary projects would be restricted to counselling and lack a core element of the mission of research: to find out what can be learned for other problem situations. Instead of defining standard conditions for idealisation, generalisation of knowledge has to be achieved by transferring models and methods from the context in which they have been developed, to other contexts, while carefully validating the conceptions of each setting. Therefore, problem analysis and bringing results to fruition are best conceived of as iterative and integrated steps (Chapter 24). In such a situation researchers and actors in the life-world collaborate to achieve: (1) recurrent validation and adaptation of empirical models in concrete situations, (2) ongoing deliberation about goals, and (3) recurrent monitoring of experiments and effects in order to adapt conceptions and transformation strategies.

Bringing the results to fruition, as a phase of the transdisciplinary process, relies on the synthesis of knowledge and the translation of that knowledge. This takes into account the context of the actors in the life-world who are involved in transforming practices to promote what is perceived to be the common good. Transformations can comprise new insights, and as a consequence alter the perception of a problem, thus influencing policy making and individual behaviour. Because of the uncertain empirical knowledge, contested purposes and habits relating to existing practices, it is important that practitioners learn about the strengths and weaknesses of problem-solving strategies and develop competences for implementing and monitoring progress in order to be able to adapt strategies and purposes. This influences problem-solving strategies: from the implementation of definitive (technological) solutions, to social learning about problem-solving strategies including the design of technologies and institutional structures as well as changing attitudes.

In this chapter, transdisciplinary research has been characterised by its starting point, goals and requirements. It has been argued that transdisciplinary research is necessary when knowledge about a societally relevant problem field is uncertain, when the concrete nature of problems is disputed, and when there is a great deal at stake for those concerned by the problems and involved in investigating them. In such situations, the knowledge required as a starting point for research comprises the genesis and possible further development of problems. This includes: the interpretation in the life-world (systems knowledge); knowledge about the need for change, desired goals and better ways of acting (target knowledge); and knowledge about technical, social, legal, cultural and other means of redirecting the existing behaviour (transformation knowledge). Consequently, the challenge for researchers is to grasp the relevant complexity of the problems, to take into account the diversity of life-world and scientific perceptions of problems, to link abstract and case specific knowledge, and to develop knowledge and practices that promote what is perceived to be the common good. Against this background transdisciplinary research can be distinguished from both basic and applied research by the way scientific disciplines and actors in the life world are involved in problem identification and structuring. Concurrently building a knowledge base for relating research questions to problem fields and problem-solving in the life-world has design implications, for problem analysis and for bringing results to fruition. One of these implications is to design the research process as a recurrent ordering of phases.

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