

What is a Problem? On Problem-Oriented Interdisciplinarity

Jan C. Schmidt
Unit of Social, Culture and Technology Studies
Darmstadt University of Applied Sciences
Haardtring 100, D – 64295 Darmstadt, Germany
jan.schmidt@h-da.de

The final publication is available at www.springerlink.com
Published in *Poesis & Praxis* 7(4), 2011, 249-274.

Abstract: Among others, the term “problem” plays a major role in the various attempts to characterize interdisciplinarity or transdisciplinarity, as used synonymously in this paper. Interdisciplinarity (ID) is regarded as “problem solving among science, technology and society”, and as “problem orientation beyond disciplinary constraints” (cf. Frodeman *et al.* 2010). The point of departure of this paper is that the discourse and practice of ID have problems with the “problem”. The objective here is to shed some light on the vague notion of “problem” in order to advocate a specific type of interdisciplinarity: *problem-oriented interdisciplinarity*. The outline is as follows: Taking an *ex negativo* approach I will then show what problem-oriented ID does *not* mean. Using references to well-established distinctions in philosophy of science, I will show three other types of ID that should not be placed under the umbrella term “problem-oriented ID”: object-oriented ID (“ontology”), theory-oriented ID (epistemology), and method-oriented ID (methodology). Different philosophical thought traditions can be related to these distinguishable meanings. I will then clarify the notion of “problem” by looking at three systematic elements: an undesired (initial) state, a desired (goal) state, the barriers in getting from the one to the other. These three elements include three related kinds of knowledge: systems, target and transformation knowledge. This paper elaborates further methodological and epistemological elements of problem-oriented ID. It concludes by stressing that problem-oriented ID is the most needed as well as the most challenging type of ID.

Zusammenfassung: Der Begriff des „Problems“ spielt eine zentrale Rolle in den aktuellen Bemühungen, interdisziplinäre Forschung bzw. Interdisziplinarität zu kennzeichnen. Interdisziplinarität (ID) wird als „Problemlösen an der Schnittstelle Wissenschaft, Technik und Gesellschaft“ und als „Problem-Orientierung ohne Methodenzwang“ angesehen (vgl. Frodeman *et al.* 2010). Doch die semantisch unbestimmte Redeweise vom „Problem“ ist alles andere als unproblematisch. – Der Ausgangspunkt dieses Papiers liegt in einer Defizitdiagnose, nämlich dass Diskurs und Praxis interdisziplinärer Forschung *Probleme mit den Problemen* haben. Ziel der folgenden Ausführungen ist es, hier gegenzusteuern und den vagen Begriff des „Problems“ kritisch zu beleuchten. Damit kann ein spezifischer Typ der ID positiv ausgezeichnet werden: die Problem-orientierte ID. – Zur Agenda: Zunächst wird unter Rückgriff auf etablierte Unterscheidungen der Wissenschaftsphilosophie eine Abgrenzung vorgenommen und gezeigt, was Problem-orientierte ID *nicht* meint: Objekt-orientierte ID („Ontologie“), Theorie-orientierte ID (Epistemologie) und Methoden-orientierte ID (Methodologie). Unterschiedliche Denktraditionen stehen für diese verschiedenen ID-Typen Pate. Sodann wird im Hauptteil des Papiers der Begriff des Problems untersucht. Drei notwendige Bedingungen kennzeichnen diesen in formaler Hinsicht: ein unerwünschter (Anfangs-)Zustand, ein erwünschter (End-) Zustand sowie eine Barriere, von dem einen in den anderen Zustand zu gelangen. Diese drei Elemente umfassen drei Wissenstypen: System-, Ziel- und Transformations-Wissen. Das Papier zeigt weitere methodologische und epistemologische Aspekte der Problem-orientierten ID. Schließlich werden Bedarf und Herausforderungen an Problem-orientierter ID herausgestellt.

1. On the problems with the problems ...

In the wake of the discourse on interdisciplinarity the notion of “problem” plays a key role. Interdisciplinarity is considered a “problem-orientation beyond disciplinary boundaries”. However, the reference to the buzz word “problems” is not very specific. Problems can also be found in traditional disciplinary sciences as well as in the life-world. Karl Popper stresses that “we study not disciplines, but problems. Often, problems transcend the boundaries of a particular discipline.” (Popper 2000:97) In consequence, there does not seem to be any *differentia specifica* between interdisciplinarity and disciplinarity, or between interdisciplinarity and day-to-day action. Problems seem to be everywhere and nowhere!

In spite of the lack of distinction, Julie Thompson Klein *et al.* (2001) characterize interdisciplinary research by its reference to problems: interdisciplinarity is “joint problem solving among science, technology, and society”. In the same vein, Jürgen Mittelstraß stresses that “by ‘transdisciplinarity’ we describe types of research and sciences that transcend disciplinary orientation in a problem-oriented manner.” (Mittelstraß 1998:44) Hartmut von Hentig regards interdisciplinarity as a reflexive term: “interdisciplinarity reminds us that the departmental structure of universities restricts them to fulfilling the real tasks that are posed by the world to the science system.” (Hentig 1972:19) Similarly, Jochen Jaeger and Martin Scheringer argue in favor of a “problem-related form of science”: “Problem-orientation without method constraints.” (Jaeger/Scheringer 1998) Egon Becker and Thomas Jahn conceptualize *Social Ecology* as a research program in which the “challenging problems are not simply given via the disciplines, but are deeply rooted in societal practice.” (Becker/Jahn 2006:310) Gotthard Bechmann situates “problem-oriented research in between public policy and science”; he draws attention in particular to Technology Assessment (TA) (Bechmann/Frederichs 1996). According to Michael Decker, TA is in its origin interdisciplinary research that “identifies and works on trans-scientific problems” that are “political or societal problems.” (Decker 2010:145) Carl Friedrich Gethmann formulates requirements on TA: “Any kind of rational judgment of the consequences of science and technology has to provide propositions how to solve transdisciplinary problems.” (Gethmann 1999:4) Günter Ropohl advocates a concept for a Synthetic Philosophy that is a kind of philosophy based on his General System Theory wherein problems constitute the very core: “Transdisciplinary sciences define their problems with regard to life-world relevance.” (Ropohl 2005:29; cf. Ropohl 2002) Armin Grunwald seeks quality criteria to specify the added-value of “problem-oriented research”; he points to relevance decisions before or at the beginning of problem-oriented research projects:¹ The problem-framing process is based on normative relevance decisions (Grunwald 2002). However, is the *common parlance* about problems self-evident?

Not at all! The notion of problem remains as unclear as the term “interdisciplinarity”—although great efforts have been made in pre-projects at the TA office of the German Bundestag (TAB), at the Europäische Akademie Bad Neuenahr-Ahrweiler or at the Institute of Social-Ecological Research (ISOE). Karl Popper’s point—*Life always is problem solving!*—highlights the under-determination of the notion of problem. It seems that everywhere in our life-world and in disciplinary sciences problems are being identified, framed, worked on and solved: physics, biology, or sociology appear to be problem-oriented or, more than this, problem-determined. If this broad understanding were prevalent there would not be any *differentia specifica*.

The objective of this paper is to foster and facilitate the theory discourse on interdisciplinarity, in particular a conceptual foundation of problem-oriented

¹ “In the early stages of projects involving integrative research one comes to an agreement on which areas of inquiry and issues are relevant for the purpose in question and its context. It is not an exaggeration to say that such prior decisions are among the major challenges of problem-oriented research.” (Grunwald 2004:10) (my translation, J.C.S.)

interdisciplinarity by finding a demarcation line between this type of interdisciplinarity and other types. In the following I will try to contribute to a clarification of both terms—“problem” and “interdisciplinarity”. With reference to well-established differences within the philosophy of science, a plurality of four different dimensions will be proposed: interdisciplinarity with regard to objects (“ontology”), knowledge/theories (epistemology), methods/practices (methodology), and problem-orientation.

2. What problem-oriented interdisciplinarity is not ...

The discourse on interdisciplinarity (ID) is normative and, to some extent, appellative. It starts with an uneasiness, disappointment, and criticism. The advocates of ID identify deficits within the science system or, more generally, in academia and the sciences themselves (cf. Mittelstraß 1987). They call fundamental assumptions into question: academic status quo, research objectives, education processes, rationality, methodology.² Almost all who mention “ID” are pursuing goals, e.g., to solve pressing societal problems, advance academic knowledge, unify cognitive life-worlds, and ensure economic growth. Describing science from an unattached observer’s perspective is not their aim. Rather, they intend to change, renew and restructure sciences, research and development, or society at large. ID is therefore a means and a medium, not an end-in-itself. Speaking of ID, Erich Jantsch (1970) proposes a “self-renewal” of academia and the university system, entailing a change of society at large. Today, the revolutionary attitude is being deconstructed. Jan Fagerberg (2005:8) regards ID as the source of “innovation and long-term economic growth.” In all approaches, normativity is involved. An implicit societal theory—how are contemporary technoscientific societies to be understood and how should the societal future be shaped—is always present when the buzzword “ID” appears. ID is an eminently political term (cf. Frodeman et al. 2010; Weingart/Stehr 2000).

Two assumptions are most prominent: the *boundary premise* presupposes a dichotomy or, at least, a separation between disciplines or between academia and society; the *transgression premise* assumes that options for overcoming boundaries do exist: transfer, integration, unification. ID obviously gives rise to a boundary paradox: elimination *and* conservation of boundaries at the same time. If “elimination” were to succeed, ID would dissolve. Instead of boundary paradox, a more appropriate term would seem to be *boundary dialectic*, which is similar to Hegel’s ‘Aufhebung’. A twofold requirement on a philosophical reflection of ID is to provide a concept of both, separation *and* integration. By considering boundaries, the position of ID-integrationists, unificationists and reductionists can be rejected. The boundary theme is an old topic of philosophy, intrinsically interlaced with monism, dualism and pluralism, and with reductionism and non-reductionism. Over the last 30 years prominent philosophers and social scientists have studied boundaries—but not explicitly the notion of ID (e.g. Star/ Griesemer/ Lowy; Beck; Luhmann/ Parsons; Latour; Haraway; Bauman; Foucault; Serres).³

² According to Adorno (1969: 158), “Critique of knowledge is critique of society, and v.v.” Bruno Latour (1999:iv) argues that epistemology and politics “go hand in hand.”

³ I should be explicit and state that I will not follow the one-sided unity view of interdisciplinarity. For instance, Julie Thompson Klein argues that “the modern concept of interdisciplinarity has been shaped in [...] major ways, [in particular] by attempts to retain and, in many cases, reinstall historical ideas of unity.” “The roots of the concepts lie in a number of ideas that resonate throughout the discourse—the ideas of a unified science, general knowledge, synthesis, and the integration of knowledge.” In addition, throughout this paper unity is regarded just as *one* defining element—one that has to be clarified. Other, obviously contrary elements refer, for instance, to non-reductionism and pluralism. Indeed, some interdisciplinarians advocate unity and reductionism, others pluralism and non-reductionism. Thus, interdisciplinarity should be regarded as a relational term that carries an indissoluble tension between unity and plurality, between reducibility and irreducibility, and between reductionism and antireductionism. My main argument against the advocates of unity is that “interdisciplinarity” would be meaningless and powerless if it just aimed to reinstall unity and to enable more reductions. If this were the case, physics would be the most successful way to practice interdisciplinarity. Further, it is even more paradoxical that, should interdisciplinarity finally win through, unity would be reached and, at the same time, interdisciplinarity would dissolve. Because of these intrinsic problems my position differs from the unity view. I therefore present my proposal for a plural framework for understanding “interdisciplinarity”.

Against this background—the twofold requirement of “ID”: separation *and* integration—, we will now consider four types of ID and thereby draw a distinction between problem-oriented ID and other types. We will employ the well-established distinction between objects/reality (“ontology”), knowledge/theories (epistemology) and methods/practices (methodology) (cf. Schmidt 2002/2003/2005/2007a/2010; Jungert et al 2010; Kline 1995).

When we speak of “problem-oriented ID” we do not refer to an *object-oriented type of ID*. “Interdisciplinary” may refer to objects or entities (“ontological” type; object-oriented ID). The historically established functional differentiation of scientific disciplines does not seem to be totally contingent. Rather, it mirrors aspects of the structure of reality itself. Edmund Husserl, Nicolai Hartmann, Alfred North Whitehead, and others have favored a structurally layered concept of reality. Boundaries between the micro-, meso-, and macro-cosm seem to be evident. Interdisciplinary objects are thought to be located or constructed within the structure of reality. They lie *on* the boundaries between different micro-, meso-, macro-, and other cosms or *within* the border zones between disciplines; examples are: brain-mind objects, nano objects, or the hole in the ozone layer. In order to advocate this position one has to presuppose an ontological realism, or at least a real-constructivism⁴ concerning the objects, interlaced with a layered concept of reality, and, based on this, an ontological non-reductionism.⁵ Old and ongoing issues about ontological monism, dualism and pluralism emerge in this debate. “ID” here does not mainly refer to knowledge, methods, or problems, but to an external, human-independent reality. Some weaker versions of this position do not claim the timeless (“Platonist”) existence of “interdisciplinary” objects. The future development of science may shift these objects to domains of new disciplines or, on the other hand, it may be shown that they belong to fields of classical, already existing disciplines. Or, one may consider interdisciplinary objects to be created by the extended use of technologies (“real-constructivism” or “materialistic constructivism”) or cognitively constructed by sciences themselves (classical “cognitive constructivism”, “idealistic constructivism”), for instance, the hole in the ozone layer, nanobots, or some of the virtual objects which are nowadays the objects of inquiry of the computer sciences.⁶ Donna Haraway’s *hybrids*, Bruno Latour’s *quasi-objects*, Susan Leigh Star’s *boundary objects*, Davis Baird’s *things* und Alfred Nordmann’s *technoscience ontology* can be regarded as real-constructed interdisciplinary objects.⁷

Thereupon, problem-oriented ID obviously does not refer to *theories or concepts*, resp. *interdisciplinary theories* (of the epistemological type). If we want to talk about theory-oriented ID, the pertinent question is, can any particular type of knowledge, recognition or scientific truth be called “interdisciplinary”? Can we demarcate interdisciplinary knowledge from disciplinary knowledge or from non-scientific knowledge? Is there a unique context of justification of interdisciplinary theories? Do interdisciplinary models, laws, explications, descriptions and explanations exist? Possible ID concepts are meta-theories, which can be applied to describe very different disciplinary objects. According to this view, an interdisciplinary theory highlights structural similarities between certain properties of objects from various disciplines. Such a theory is not reducible to a disciplinary one—that is, interdisciplinary theories do not

⁴ The position of *real-constructivism* is not fully developed in the philosophy of science, although the “new experimentalism” has broadly argued in favor of it. This position traces back to Francis Bacon in the early 17th century. Also, some aspects can be found in the pragmatist tradition. Today I. Hacking (1983), B. Latour and S. Woolgar (1979) support this position.

⁵ Ontological reductionism is known as the stance stating that the world consists (totally) of atoms or other fundamental material entities (“materialism”) or, on the contrary, of mental entities (“idealism”).

⁶ They have not existed since the beginning of the world. It might be disputed whether these objects are by themselves “interdisciplinary” or, on the other hand, whether they are just perceived, described, or shaped from an interdisciplinary perspective. Although it might be controversial whether a *particular* object is to be labeled “interdisciplinary” – for instance, a technical object may be seen as a disciplinary object of engineering sciences or as an interdisciplinary object, – interdisciplinary objects seem to exist at least for a certain time.

⁷ A similar line of thought is found in an extensive study by Bergmann et al. (2010, 106) in which the concept of transdisciplinary “integration through *boundary objects*” is introduced. “Without an identification [or even construction] of Boundary Objects, mutual work cannot begin, let alone be organized.” (Bergmann et al. 2010:106) More specifically, according to the study, “materialization is also the basis for the integrative effect of artifacts. One could describe them as integrative interfaces that have become material.” (ibid.)

fit in the disciplinary framework. Epistemological non-reductionism with regard to disciplinary theories is the most compelling position. The so called “structural sciences” such as complex systems theory are prominent examples of meta-theories. The goal is a cognitive integration and theoretical synthesis of knowledge. Similar to complex systems theory are theories such as self-organization theory, dissipative structures, synergetics, chaos theory, nonlinear dynamics, fractal geometry, and catastrophe theory. Most of these theories were established in the late 1960s and early 1970s, although some foundational work dates back to the late 19th century (cf. Mainzer 1996; Schmidt 2008). Hermann Haken, the founder of *synergetics* in the 1960s, regards synergetics as an “interdisciplinary theory of general interactions” (Haken 1980). In fact, this type of ID, which might be characterized as metadisciplinary— or at least non-disciplinary—abstract knowledge, is not new. Fundamental ideas can be found in works from the 1940s and 1950s. The physicist and philosopher Carl Friedrich von Weizsäcker coined the term “structural sciences” (Weizsäcker 1974:22). Weizsäcker writes that structural sciences “study their objects regardless of disciplinary origin and in abstraction from disciplinary allocation”. Today, complex systems theory describes process phenomena—such as pattern formation, self organization, critical behavior, bifurcations, phase transitions, structure breaking, and catastrophes—in different disciplinary branches.

Moreover, the specification of problem-oriented ID does not so much take into account *method-oriented ID* or *interdisciplinary methods* (methodological type)—even though this dimension does play a role. Jochen Jaeger and Martin Scheringer conceptualize problem-oriented ID as “research without disciplinary constraints in methods.” (Jaeger/Scheringer 1998; cf. Mittelstraß 2005) The central issue with regard to designating a method-oriented ID is whether or not there is a special canon or methods, rules, empirical settings and hermeneutic forms which typify ID and positively determine it. One basic question regarding methodology is *how* we can attain knowledge and insight. Rough classical categorisations distinguish between empirical and hermeneutic, nomothetic and ideographic, explaining and understanding methods as well as those of the natural sciences and the humanities (cf. Rickert 1986).⁸ As regards ID, central questions are: Do interdisciplinary methods and actions exist? Is there a specific context of discovery? Interdisciplinary methodologies are thought to be irreducible to a disciplinary methodology.⁹ Biomimicry/biomimetics—sometimes used interchangeably with “bionics”—is an excellent example of an interdisciplinary method (Benyus 2002; Rossmann/Tropea 2004). At the core of the biomimicry methodology is the cross-fertilization between two disciplines: biology and engineering sciences. Biomimicry claims to be a “transfer methodology” from biology to engineering sciences, and probably—which is mostly not acknowledged—vice versa. The central, popular and of course questionable idea of biomimicry can be summarized as follows: “learning from Nature” in order to “inspire technological innovations” and to develop efficient artifacts and processes (cf. Benyus 2002). Nature seems to provide excellent ideas and inventions that can be used to construct technology.¹⁰ However, interdisciplinary translations are based on models. “Learning from Nature” therefore means learning from models of Nature. What we call “Nature” is not a given but is constructed. Immanuel Kant argued that we have to be aware that Nature is perceived and cognitively constructed from the perspective of technology; biomimicry constructs models of biological nature from the perspective of engineering sciences. Thus, the transfer method is not a one-way street. A robot, for example, mimics an ant, but at the same time the ant has

⁸ In his work “Kulturwissenschaft und Naturwissenschaft”, H. Rickert writes in the introduction to the 20th century boundary: “There is mostly agreement today that the specialist sciences fall into two categories [...] which are interconnected by common interest” (Rickert 1986:1). Rickert continues with his well-known dichotomy nomothetic vs. ideographic.

⁹ In other branches it is clear that hermeneutics is not reducible to empirical measurement and quantitative objectivity; empirical measurement and data analysis methodologies are not reducible to hermeneutics (cf. Rickert 1986)

¹⁰ As far as the protagonists of Biomimicry are concerned, “nature reaches its goals efficiently and economically, with a minimum of available energy and resources.” (ibid.)

been investigated and described from a technological perspective.¹¹ Besides biomimicry, there are other examples of interdisciplinary methodologies. Econophysics is similar to biomimicry. It methodologically organizes a transfer between physics and finance/economics (Mantegna/Stanley 2000; McCauley 2004). In addition to these transfer methodologies, a new kind of non-disciplinary methodology of knowledge production has emerged over the past 50 years: mathematical modeling and computer-based simulations. Modeling tools and simulation techniques are not only applied in various disciplines—for instance, in order to reduce the costs of experimentation or to improve the prediction accuracy. They are also used and developed pragmatically to integrate knowledge from different disciplinary domains (cf. Nersessian 2008). Special kinds of integrative methodologies have been developed in the realm of Technology Assessment, Social-Ecological Research and Transdisciplinary Sustainability Research. However, the integration methodologies are still an ongoing challenge throughout this field—in particular when integrating descriptive, normative and abductive forms of knowledge are involved (cf. Grunwald 2004).

3. What problem-oriented interdisciplinarity is ...

It is striking that the three types of ID elaborated above do not cover the whole breadth of the notions of ID that are present throughout the recent discourse. We therefore have to add another type that does justice to the discourse. It is frequently stressed that the world has problems and the academic world has departments and disciplines. It would appear that the world's problems and the academic world, in particular the university system, are incommensurable. The *incommensurability thesis* is the point of departure of those who advocate another type of ID. It is sometimes called “transdisciplinarity”, with emphasis on “joint problem solving among science, technology, and society” in order to “manage complexity” (Thompson Klein et al. 2001).

This type of ID focuses on the starting points, goals and purposes of ID research activities—in other words, on the constitution, identification and framing of problems. Problems make this ID type necessary and indispensable. Throughout the ID discourse, it seems to be a widespread position that “problem-oriented research has to be interdisciplinary or transdisciplinary in its very core” (Bechmann/Frederichs 1996:17; cf. Ropohl 2002; Bogner et al. 2010). Although the reference to challenging, complex real-world problems and the call for ID is popular today, it has its own history. In an epochal-breaking approach, Alvin Weinberg was the first to suggest the term “problem” in the context of research for society (Weinberg 1972). Weinberg speaks of “big problems”, such as challenging and pressing questions of national security, the future of the social welfare system, the science policy of research and development programs, and environmental problems. Weinberg's still-relevant diagnosis was: the science system does not have any answers to pressing societal questions. In order to overcome the deficits Weinberg developed the concept of “trans-science” (Weinberg 1972).¹² In line with this approach, but slightly earlier, Erich Jantsch proposed a “purposive understanding of ID” and a “purpose-oriented ID”: An explicit reflection on and revision of purposes should be regarded as the highest level of ID that Jantsch called “transdisciplinarity” (Jantsch 1972:100f).¹³

ID problems are regarded as being external to disciplines or to academia. They are primarily societal ones that are (pre-) defined by society, e.g., lay people, politicians, and stakeholders. This approach to the societal relevant starting point of research activities comes

¹¹ Construction and reconstruction, intervention and representation, here: technology/engineering science and biology are merged. Biomimicry does not aim to produce only knowledge but to produce technical artifacts. Analogies play an important methodological role.

¹² The OTA Act of 1972 also contains the notion of problem; it is the intention of the OTA to address “existing and emerging national problems” (OTA 1972).

¹³ In addition, the approach by Chubin et al. on “ID” by referring to “theory and practice of problem-focused research” was very influential on the ID discourse (Chubin et al. 1986).

close to today's science-based enterprises such as Technology Assessment (TA), sustainability science and global chance science, which can be considered as examples of this type of ID (Decker 2007; Pohl/Hirsch Hadorn 2006). Problem-oriented ID reflects on and revises the problem perception; the starting points of science and technology programs are at the focus. This is interlaced with problem framing and agenda setting (Becker/Jahn 2006; Schmidt 2007a/b; Schmidt 2010; Hoffmann 2010; Bergmann et al. 2010; Liebert/Schmidt 2010b; Krohn 2010).

Because problems precede both the context of discovery and the context of justification—in other words: methods/means and theories/models—, problem-oriented ID is a specific type of ID that cannot be subsumed under the label of method-oriented ID or theory-oriented ID. The teleological structure in the process of knowledge production is most evident but not always acknowledged.¹⁴ The first step in scientific inquiry—the problem seeing and agenda setting, the volition or intention to obtain knowledge—is often judged to be a contingent factor. It has been widely ignored or devaluated by the philosophy of science, although extended work has been done on problems called “wicked problems” (cf. Norton 2005, 131f/159f).¹⁵ Philosophical ethics, in particular discourse ethics developed by Apel and Habermas, did not follow the mainstream practice of neglecting the very starting points, including the perception and framing of problems. As well, concepts of Rationalist Technology Assessment (RTA, pre-studies, pre-projects) (Grunwald 1999), of Prospective Technology Assessment (ProTA) (Liebert/Schmidt 2010a/b) and of Social-Ecological Research (Becker/Jahn 2006) have addressed the issue of problems as the starting point of any problem-oriented interdisciplinary project.

Unfortunately, these efforts did not have a broader influence on the societal, scientific and philosophical understanding of science. The neglect of the notion of problem can also be seen as a consequence of the implicit predominance of analytical philosophy of science.¹⁶ Analytical philosophers of science have always been reluctant to consider normative aspects within science's core; they more or less still parade the value-free view of natural sciences. Accompanied by the notion of problem, normativity is nevertheless existent. Framing knowledge production from the angle of the “problem” may contribute to the critique of the self-stylization of science—often advocated by philosophers of science—as a value-free enterprise. Those who talk about problem-oriented ID cannot talk at the same time about value freeness. Therefore, the notion of problem can be regarded as a reflexive term that calls for an explication of *who* is considering *what* as a problem and *why*. In fact, problems can be considered as a kind of epistemology-ethics hybrid that carries a call-to-action: problems are seen as negative, as indicating a deficit state that needs to be addressed; problems have to be eliminated.

Although philosophers have not addressed the notion of problem, the word is present in the works of many prominent philosophers. Karl Popper stresses that “good hypothesis has to include risky problems”, Thomas S. Kuhn believes that a “paradigm determines the choice of problems”, Imre Lakatos coins the notion of “progressive vs. degenerating problem shift”, and Larry Laudan regards “sciences as problem-solving action”. Popper underlines that “we aren't studying subjects [= Fächer], but problems. Problems can transgress the boundaries of a certain predefined domain of a certain scientific discipline.” (Popper 2000:97) Popper, however, like other prominent philosophers of science does not explicate the term “problem”; it remains vague. Although Kuhn is not more precise than Popper, he presents an idea that comes close to the recent discourse on problem-oriented ID. As early as in 1962, Kuhn perceived a professional blindness of scientists with regard to societal problems: “A paradigm

¹⁴ Jürgen Habermas underscores the interests of the sciences and the purposes interlaced with the research processes (Habermas 1970).

¹⁵ The lack of reflection on purposes turns out to be a deficit in specifying this fourth type of ID. The reflection on and revision of purposes was—according to Erich Jantsch in the 1970s—a unique criterion for demarcating ID from disciplinarity (Jantsch 1970).

¹⁶ The neglect of problems seems to be rooted in a deep kind of self-mythologization of scientists and (analytical) philosophers of science. According to Ludwig Wittgenstein, “the experimental method gives substance to the misleading belief that we have the means to cope with the problems that worry us.” This is a misperception insofar as “problems and methods do not match.” (Wittgenstein 1999:xiv)

can isolate the scientific community from socially relevant problems that resist being reducible to the form of a puzzle insofar as such problems cannot be expressed in the terminological and instrumental means of the paradigm.” (Kuhn 1996:51) Kuhn adds: “The societally pressing problems, such as finding a therapy against cancer or concepts for a lasting state of peace, are certainly not puzzles.” (ibid.)

Problems are also not to be considered puzzles because they do not have clear solutions in a way that scientific puzzles are assumed to have. An implicit distinction between problems and solutions is present throughout the discourse on ID. Problem-oriented ID does not offer solutions in the way that engineering sciences are able to come up with a new artifact to solve a technical problem.¹⁷ Rather, in problem-oriented ID much is achieved when a problem is constituted, framed and clarified—in other words: when rational arguments underlining that a certain situation is a problem are presented. Problem-oriented ID may offer advice on possible solutions to problems. However, it does not solve the problems itself: it supports a decision but does not provide the actual decision. The science system itself, and thus problem-oriented knowledge production, is not legitimized to recommend any kind of solution; otherwise democratic societies would turn into expertocracies.¹⁸

4. Formal clarification: problems

How do we know that X is a problem?¹⁹ Gereon Wolters defines a problem as the “incompatibility of some propositions (the ‘problems’) with the set of those propositions that are considered as true or evident.” (Wolters 2004:347) To put it in other words: A problem is what does not fit the general body of accepted knowledge; the notion of problem thus emerges as a concept of relations; it is based on the relation between two or more propositions.

The approach from the angle of philosophy of science with its reference to incompatibility is a necessary, but insufficient condition to clarify what a “problem” is. Problems call for action; the notion cannot be restricted to propositions and general cognitive aspects that are traditionally part of philosophy of science. Therefore, action theory (and philosophy of action) has to complement the philosophy of science in order to give further substance to the notion of problem. An integrative approach has been developed from different angles by Dietrich Dörner and Roland W. Scholz. They combine system theory with action theory, philosophy of science and cognitive psychology. Although Dörner does not focus explicitly on ID, his conception of problems can serve as a framework for the clarification of what problem-oriented ID is. According to Dörner, a problem is based on a relation of three elements that encompass normative and descriptive, qualitative and quantitative aspects: (1) an undesired (initial) state of the current situation, including an anticipation of prospective futures; (2) a desired (final) state of how the future should look like and (3) a barrier, obstacle or hurdle²⁰ that hinders or inhibits the transformation of the present-day’s undesired state into the desired state (Dörner 1995). Roland W. Scholz takes a similar stance. He goes beyond Dörner by assigning a pivotal role to each piece of knowledge: without language, knowledge and recognition, we cannot speak of a problem. According to Scholz we can speak of a problem if and only if (1) there is a difference or divergence between (a) a *target knowledge* that refers to the desired state in the future (“target state”) on the one hand and (b) a *system knowledge* that reflects the current state (“actual situation”) on the other hand, *and* (2) the non-existence of an appropriate *transformation knowledge* that facilitates the transfer from the actual situation to

¹⁷ Not only are purposes and means driving on a roundabout – the same can be said of problems and solutions.

¹⁸ “A problem”, Miguel de Unamuno writes in his essay *How to make a Novel*, “does not presuppose the existence of a solution in the sense of an analytical clarification or resolution of the problem, but rather a construction or creation. It is resolved within action.”

¹⁹ The term “problem” traces back to Ancient Greece; it means task or issue. Thus, in English usage today the notion comes much closer to the Greek origin than the German understanding, which is, indeed, much broader and more general.

²⁰ Becker and Jahn do not use the term barriers, but instead they speak of “hurdles”: “Therein [= in the systemic theories of emergence] systemic problems are described as hurdles to the reproduction and evolution of emergent systems.” (Becker/Jahn 2006:312)

the target state. The transformation knowledge encompasses action knowledge, about how to overcome barriers by certain decisions in order to enable specific actions (cf. Scholz 2011).

However, that is not all to be said about the formal aspects of “problems”. A temporal dimension can and should be considered. Problem-oriented ID contributes to the perception and framing of a situation as a “problem”. The word situation can refer to an *actual* state or, as an extension of Dörner’s and Scholz’s approach, to a *future* state. A certain future state may be largely undesired—a dystopia—and the actual state may be the desired one, for instance regarding global change effects. In this case, a problem has not yet emerged but might or will emerge in the future. Although it does not yet exist, an anticipated problem is considered as “real”; it induces a call for action. Problem-oriented ID is inherently future-oriented. It can be regarded as (anticipatory) precautionary research *ex ante*: problems should be hindered from emerging, for example by a *problem radar* based on a precautionary principle and supported by methods of technology assessment.

In summary, problem-oriented ID aims to offer system, target and transformation knowledge, including a time-sensitive, temporal dimension and an *ex ante* reflection on prospective future states—this is what we call *problem knowledge*. The balance and interplay of the three kinds of knowledge will always remain a matter of dispute that needs agreement in different contexts. It is undisputable that problem knowledge is intrinsically interlaced with action knowledge.²¹ The notion of “problem” encompasses thus (i) the assessment of the actual or future state—from the angle of an anticipated target state—as being undesired or negative (*negativity thesis*) and (ii) the barrier to reaching or avoiding the target or anticipated state (*barrier thesis*). If an actor does not have what he or she wishes to have or possess, and if he or she cannot obtain it, the actor has a problem: if we desire to live in a world without atomic weapons or would like to travel without Carbon-Dioxide emissions, but cannot do so, so we are faced with problems. This notion of problem carries certain elements of action theories, including aspects of “inhibited effecting” (Wright 1991) and “thwarted realization of objectives and purposes” (Grunwald 2002). All this touches upon philosophical ethics, philosophy of science, decision and planning theory, technology assessment, risk research and scenario techniques. It can be considered as a major part of system thinking.²²

5. Clarification of methodological assumptions: boundaries

Throughout the discourse on problem-oriented ID, the assumption of boundaries is striking and gives rise to the boundary paradox (see above). A clear demarcation is considered to exist between sciences and society—that is a strong thesis of an *internal-external-dichotomy*.²³ Insofar as problem-oriented ID aims to transgress the borderline, it has to assume that it exists: the boundary is a necessary condition for talking about problem-oriented ID.²⁴ Problem-oriented ID intends to transgress this boundary in two ways. It takes up *external* (= to science) societal problems, works on them *internally* and transfers the results to the societal domain in order to contribute to *extra-scientific* societal problem-solving. In the 1970s, the underlying thesis of the internal-external dichotomy was broadly present in the *finalization thesis* advocated by Wolfgang van den Daele, Wolf Krohn and Gernot Böhme: in certain phases of the evolution of sciences *external* goals drive *internal* development. Based on Kuhn’s terminology, the external goals are driving the pre- and post-paradigmatic phases (Böhme et al. 1974/1978). Similar dichotomies are present in concepts that emerged later, e.g., the theses of

²¹ Cognate aspects can be found in the works on conceptual elements towards a theory of TA (technology assessment; cf. Grunwald 2007). TA is characterized by a threefold orientation: consequence, science and consultancy, which comes close to target, system and transformation knowledge.

²² Similarities might be perceived between problem-oriented ID and Mode-2-science as described by Gibbons et al. (1994).

²³ “Internal” and “external” refer to the science system.

²⁴ Therefore, in line with the terminology introduced by Thomas F. Gieryn (1983), problem-oriented interdisciplinarians always need to do a kind of a “boundary work”: “demarcating science from non-science” is a prerequisite for talking about “problem-oriented ID”.

post-normal, post-academic, mode-II- or techno-sciences (cf. Schmidt 2007a; Kastenhofer 2010).

The kinds of problems addressed by problem-oriented ID are therefore *not* (i) disciplinary problems internal to science, (ii) problems based on major (interdisciplinary) objects²⁵, (iii) problems at the intersection of different disciplines or, (iv) engineering or technical problems (cf. Jäger/Scheringer 1998:11f/18). For these kinds of problems the borderline between science and society is irrelevant. Conversely, the boundary assumption is indispensable for the notion of problem-oriented ID; the borderline needs to be transgressed. Therefore, problem-oriented ID can be regarded as a translation or circulation science—from external to internal and subsequently from internal to external. The problem (external to science) has to be translated in order to constitute a scientific object. According to John Dewey, the constitution or construction of the object is a major challenge: “The character of a danger or threat that is predominant in a certain situation has to be transformed into an object of inquiry in a way that makes the problem definable and, thus, fosters the development of methods and means for resolving it.” (Dewey 2001:223) Unfortunately, this fundamental transformation (translation, object constitution, or “problem transformation” cf. Becker/Jahn 2006:314f) is mainly neglected from the philosophical perspective.²⁶ In particular, philosophers of language have remained silent although the translation procedures involved can be regarded as major parts of philosophy of language. Criteria for a successful transfer from one domain to another have not yet been developed. What happens on the way from (a) societal problem perception, (b) extra-scientific problem constitution, (c) scientific problem definition, (d) discipline-oriented problem decomposition, and (e) the synthetic procedures of backward translation to the extrascientific, societal realm? This way is certainly not a mono-causal process, but rather an iterative one. Egon Becker und Thomas Jahn employ the term “problem dynamics“ to describe the transfer between science and society as well as within the science system (Becker/Jahn 2006:310). Problems and their transfer turn out to be the central issue in the methodology of ID. According to Christian Pohl and Getrude Hirsch Hadorn “the core element of transdisciplinary research is the question of how problems are to be identified, framed and structured within a broad area under consideration.” (Pohl/Hirsch Hadorn 2006:40)

Problem-oriented ID therefore faces many methodological challenges—from the framing of the problem at the very beginning to the various transfer and translation procedures to the final outcome. It should also be mentioned that compared to standards of disciplinary sciences, this type of knowledge is exposed to higher quality standards, e.g. requirement of both society and scientific community.²⁷

6. Epistemological clarification: beyond constructivism and realism

In addition to the formal and methodological issues of problems, their epistemological status is not clear at all. Two contrary positions are common, based on different epistemological background convictions. According to a realist position, problems are presupposed to exist in the “ontology” of the world, regardless of human perception.²⁸ Constructivists, by contrast, assume that problems are constituted or constructed (cf. Becker/Jahn 2006). Similarly, throughout the 1980s, the two different epistemological positions were very prominent in the debate on risks: Ulrich Beck’s *risk-realism* vs. Niklas Luhmann’s *risk-constructivism*, fueled by different accusations: alarmism and relativism.

²⁵ See above; this type was called object-oriented ID.

²⁶ There are a few exceptions, e.g., the works conducted by the Europäischen Akademie Bad Neuenahr-Ahrweiler (Decker 2001) and the Institute for Social-Ecological Research (Becker/Jahn 2006:313f).

²⁷ That these are not always met is certainly problematic – but does not alter the dual responsibility – vis-à-vis science and vis-à-vis society.

²⁸ This position is upheld, for example, by the protagonists of “social ecology” “Rather, there is a thing such as objective, societal problems” (Becker/Jahn 2006:311).

These traditional dichotomies are, however, futile. Rather, we should follow a pragmatist's approach and consider that (a) something really does exist and that this real object is the source of our knowledge production. The hole in the ozone layer is not a social or cognitive construction; the undesirable present state really does exist. A *minimal realism* seems to be the best fundament to acknowledge the matter of facts and to root the pragmatist position. (b) However, the reference or relation to something that really exists is a necessary, but insufficient condition to characterize something as a "problem". Nuclear power plants alone, including nuclear waste, or the hole in the ozone layer do not seem to be enough to identify a "problem". A certain construction, including normative based decisions, is indispensable to frame an object or a situation as a problem—and to obtain knowledge: (i) The *system construction* encompasses the demarcation decision about what the system is and what its environment is ("systems knowledge"). For instance, should we consider the proliferation of nuclear fuel and waste as part of the "nuclear power plant" system, or not? (ii) The *target construction* refers to the goal setting procedures and desired future state ("target knowledge"). (iii) The transformation-barrier (re-)construction involves framing and analyzing the barriers and obstacles that hinder us from reaching the desired future state. – Normativity is present within all types of (re-) constructions. This is part of the position of methodological constructivism and of pragmatism.

Therefore, constructivism and realism converge in problem-oriented ID—this is an epistemological position I tentatively call *constructivist realism*. Based on real situations and matters of fact, problems are constituted according to normative criteria. They can be considered as ascriptions induced by knowledge actions and procedures of knowledge production. John Dewey underlines that "only the quality of a certain [knowledge-] act shows that a doubtful situation can become a problem." (Dewey 2001:223)²⁹ In that sense, problems are not presented but generated at the science-society interface—admittedly with the necessity of a rational intersubjective justification.³⁰ A kind of naïve problem realism, on the other hand, would consider problems to be plain facts, accept them without questioning them and perceive them simply as a task to be tackled. What is typical for such a kind of naïve problem realism is the presentation of case studies in US-engineering ethics text books (e.g., Harris et al. 2005). In extreme cases the question of whether execution in the electric chair is preferable to execution by lethal injection is formulated as a *problem*. Fundamental questions about the death penalty and execution conducted by a democratic state are not posed. Problem-oriented ID rejects this kind of naïve problem realism. For each problem-oriented research project the central question at or before the beginning is: *what exactly is the problem?* Within the discourse, the problem constitution should be negotiable in a rational argumentative manner with an explicit reflection and revision of normative relevance criteria and it should be justified in each case—while never losing sight of its goals and purposes. Michael Decker explains that "the fact that the point of reference for TA is constituted by extra-scientific problems, leads to special requirements for the definition of the problem." (Decker 2010, 147)

The problem constitution is also interlaced with quality criteria in interdisciplinary projects. Since, according to Armin Grunwald, it is true that "quality properties of integrative research depend considerably on decisions of relevance which must be made [...] before beginning the research." (Grunwald 2004:1) As of now, the *problem with the problem* seems to have received far too little reflection, considering its significance for the design, process and quality of a project.

²⁹ "Indeed, a problem to be solved "technically" must first be formed as a technical problem, or "made technical". [...] Such transformation can, for instance, be achieved by way of omnipresent expert knowledge." (Mittelstraß 1992:34)

³⁰ Bechmann and Frederichs claim that, "in defining problems, politics is [constitutionally] dependent on scientific knowledge" (Bechmann/Frederichs 1996:14).

7. Operational clarification: application of the four-type ID framework

7.1. Object-oriented interdisciplinarity in the Roco-Bainbridge report of the US-NSF

The above-developed typology is not an end in itself. Rather, it offers an orientation framework and some directions in the jungle of the ID hype. Let us look at one of the most prominent programs advocating the notion of “ID”: the Roco-Bainbridge report (2002), which has been a guideline and milestone in the ID science policy of nanotechnology. What type of ID is intended and promoted by the Roco-Bainbridge report? A typology of the four kinds of ID will help to classify and to assess ID (cf. Schmidt 2003; Schmidt 2007a; Schmidt 2010).

A coherent and consistent ID theory is not the goal of the Roco-Bainbridge report and the convergence scenario of *nanotechnology*, *biotechnology*, *information technology* and *cognitive science* (NBIC scenario) developed in it (no theory-oriented ID). A patchwork of models would work well if it provided a sufficient and effective basis for technological interventions. Theories are not regarded as ends in themselves: rather, they are means and instruments. Theories are judged by the question of whether they actually contribute to the development of new technologies—or not. To put it briefly: technology is the goal, not theory; technological intervention instead of theoretical representation. On the other hand, the Roco-Bainbridge report realizes that theoretical elements are indispensable; it is not averse to theory. The patchwork of present-day engineering science limits progress. In order to promote engineering science and to develop enabling technologies, we have to “integrate what is happening.” (Roco/Bainbridge 2002:32) Because in many cases we realise that nothing is as practical as a good theory. In fact, theoretical orientation for the sake of practical relevance makes the NBIC scenario an excellent example of a “technoscience” (cf. Nordmann 2004). Natural sciences, engineering sciences, and technology are merging. Because of its practical and pragmatic orientation, however, the Roco-Bainbridge report pursues only a weak understanding of theory. A theory is not understood in the sense of a deductive-nomological type of explanation that is still the underlying objective of the unification project of physics. Thus, the report is hesitant and prefers to speak of the integration of knowledge, models and concepts rather than of a theory. Moreover, the core of the NBIC-report—that is nanoscience—is not particularly successful in terms of theory development and explanatory achievement. There is no framework theory for the nano-cosmos. Quantum and classical regimes are still opposed to each other, even though there is some progress in the area of mesoscale quantum systems. Certainly, we find progress regarding theories within the discipline of (nano-)physics. But the progress in nanophysics can hardly be called “interdisciplinary” in the context of theories.

Similar to the foregoing point concerning theories, a common method and a unified ID methodology are not the aim of the Roco-Bainbridge report (no method-oriented ID). Methods are regarded as means and tools for obtaining knowledge. What matters most are the efficiency and effectiveness of methods and not any process of unification. If unification can help to increase efficiency, it is highly desired. However, the methods we find in the NBIC branch are based on advancements in the realm of physics; some were developed in the areas of chemistry and molecular biology. A physicist, Richard Feynman, gave the first programmatic speech on nanotechnology in 1959 (cf. Feynman 1959). He declared that there seems to be “plenty of room at the bottom”. The NBIC technologies are mainly driven by methodological improvements in the area of physics. New physical instruments such as the *scanning tunneling microscope* (STM) and the *atomic force microscope* (AFM) are of major importance for the rise of nanotechnology. They stem from advanced developments in physics in the early 1980’s. If the core of the NBIC scenario is rooted in nanotechnology, then it is rooted in physics. In fact, method-oriented *disciplinarity* is widely predominant.

Concrete problems are hardly in the focus (no problem-oriented ID). The NBIC convergence can hardly be called problem-oriented. It is mainly technoobject-oriented. Only very

general and unspecific goals are formulated, such as human enhancement and fulfilling the basic needs of the Least Developed Countries. The term “new renaissance” seems to be nothing but a metaphor. The general goals are devoid of content. In contrast, problem orientation means to deliberately set goals and to reflect upon and revise purposes. Problem-oriented ID intends to focus on, to frame and to solve societal problems by explicitly reflecting on goals—and partly by developing and making use of new technologies. The Roco-Bainbridge report does not explicate or attempt to initiate a discourse about purposes. However, it seems fascinated by technological development in itself, interlaced with the vague notion of human enhancement: creating opportunities without orientation. For instance, the Roco-Bainbridge report does not have broad reservations with regard to military uses. An improvement of converging technologies for battlefield domination does not seem to be undesirable. Thus, the Roco-Bainbridge report does not fit into the reflexive concept of *problem-oriented ID* (see also the last section of this paper). In order to compensate for the lack of purpose reflection and revision, concepts of technology assessment address issues of converging technologies.

What can be said about interdisciplinary objects? Up to now my findings have been negative—there is a lack of theory- and method-oriented ID and, if any, very limited problem-oriented ID. What can be said about object-oriented ID? According to my definition in section 2, we have to take two different kinds of object-oriented ID into account. (a) The *strong version* assumes that objects are time-invariantly located on boundaries due to the universal layers of reality (universal object-oriented ID). According to ontological realism, these objects were called interdisciplinary objects. (b) A *weaker version* states that the boundaries have not always existed and do not exist for ever (partial or real-constructivistic object-oriented ID). Boundaries are constructed by the way humans construct reality. Humans construct boundaries and create objects on boundaries—in short: material boundary-objects.

In fact, the objects of the NBIC scenario are the created and constructed nanotechno-objects. They have not existed before and do not exist independently in Nature or independent of humans, although they are based on the laws of Nature: e.g., new materials, new products and processes. According to the Roco-Bainbridge report, nanoobjects form *the* fundamental basis for converging technologies. The convergence occurs in objects, not in theories, methods, or problems. The convergence of the four technologies is supposed to take place at the scale of the nanotechnoobject: “Convergence of diverse technologies is based on material unity at nanoscale and on technological integration from that scale. The building blocks of matter are fundamental to all sciences.” In the very small and real-constructed world of the nanocosm, everything seems to converge. From this perspective, the nanotechnoobjects can be labeled “interdisciplinary”. It is interesting to see how the real-constructed nanoobjects relate to physics. *On the one hand*, nanotechnoobjects belong to the domain of physics; they are located on boundaries between the quantum microcosm and the mesocosm. *On the other hand*, the Roco-Bainbridge report aims to produce instrumental knowledge about and for “enabling technologies”, and not to obtain true objective knowledge, as in “old-fashioned” physics. Although the boundaries between physics and engineering sciences are highly disputed, it is worth stressing that “converging technologies” does not mean a convergence to objects belonging to the discipline of physics but, rather, a convergence to technoscientific nanoobjects—which are objects for technological purposes. This is why we do not find a reduction to disciplinary objects such as objects of physics in the NBIC scenario, but a reduction to interdisciplinary (real-constructed) objects. In this sense, nanotechnoobjects are located between physics, chemistry, biology, and some engineering sciences. Here, as Richard Feynman, the early protagonist of nanotechnology, observed “there is plenty of room at the bottom” for non-disciplinary nanoobjects (Feynman 1959).

In consequence, (real-constructivistic) *technoobject-oriented ID* turns out to underlie the NBIC scenario. This type of ID is not a very strong one. Technoobjects would appear to be at the core of the heterogeneous and diverse fields of the umbrella term “nanotechnology”,

including electron-beam and ion-beam fabrication, molecular-beam epitaxy, nanoimprint lithography, projection electron microscopy, atom-by-atom manipulation, quantum-effect electronics, semiconductor technology, spintronics, and micro-electromechanical systems. Constructed and created interdisciplinary technobjects are essential parts of the present-day reality or the reality to come in the above fields (“ontological” type). Technobjects populate our world.

7.2. In contrast with the Nordmann report: problem-oriented interdisciplinarity

The Roco-Bainbridge report with its object-oriented understanding of ID can be contrasted with another prominent report. The Nordmann report is the answer to the American initiative drawn up by a European Commission group of experts. The Nordmann report—bearing the title “Converging Technologies: Shaping the Future of European Societies”—is a “specifically European approach to convergent technologies.” (Nordmann et al. 2004)³¹ Its core concept is called “CTEKS”: “Converging Technologies for the European Knowledge Society”. The European group does not place its main focus on some sort of self-improvement of humankind (“human enhancement”), but, more comprehensively, on societal innovation processes. Its goal is to “expand the circles of convergences”: it is not the technologies themselves which are meant to converge but the goals of technology development and research agendas (see below).

Not unlike the Roco-Bainbridge report, the Nordmann report aims at promoting ID as an instrument for creating innovation: “strong interdisciplinarity for research. [...] Research is needed about the processes of innovation and diffusion, the economies of artificial environments, conditions for multidisciplinary, interdisciplinary, and transdisciplinary work.” (Nordmann et al. 2004:45/41)³² The Nordmann report is reflexive as long as ID is not considered as simply given or easily produced. Rather, ID creates independent research questions: research *about* ID as research *for* ID – and thus the condition of the possibility of innovation. But it is not just the meta-issue of ID which distinguishes the Nordmann from the Roco/Bainbridge report. It is also the understanding of ID which is different. The CTEKS concept advocates problem-oriented ID. First of all, another convergence circle must be chosen for this, comprising more than the four technology types described in the Roco/Bainbridge report (“NBIC technologies”) as well as the associated techno-sciences. The additional convergence circle of the Nordmann report refers to: “nano-bio-cogno-socio-anthro-philo-geo-eco-urbo-orbo-macro-micro”. For this, the Nordmann report uses the term “converging technologies”; thus it does not accept the narrow American definition of the term concerning limitations to NBIC technologies.

But not just the convergence circle is wider and broader. Especially that which converges is different: “Converging technologies converge towards a common goal [or shared visions]” (Nordmann et al. 2004:4). The Nordmann report advocates *convergence(s) of* (and in the) *goal(s)*, while the Roco/Bainbridge report prefers a *convergence of* (and in the) *ob-*

³¹ The European Commission drew attention to CTs in the middle of the 2003 issue of the *Foresighting Europe* newsletter. It featured a report about two NBIC conferences in the US that considered *Converging Technologies for the Improvement of Human Performance*. The newsletter’s editorial continued: “In order to deal with the questions developed in the US NBIC report, the Commission envisages the establishment of a high level expert group on Converging Technologies.”

³² “Interdisciplinarity should be strengthened, beyond planned or institutional collaboration, in program calls and research policies from the Commission and from the European nations” (Nordmann 2004:4). Furthermore, “CT modules should be introduced at secondary and higher education levels to synergize disciplinary perspectives and to foster interaction between liberal arts and the sciences” (ibid.:5). “Commission and Member States need to recognize and support the contributions of the social sciences and humanities in relation to CTs, with commitments especially to evolutionary anthropology, the economics of technological research and development, foresight methodologies and philosophy” (ibid., 5). And “A permanent societal observatory should be established for real-time monitoring and assessment of international CT research, including CTEKS. [...] That the Commission implement a ‘EuroSpecs’ research process for the development of European design specifications for converging technologies, dealing with normative issues in preparation of an international ‘code of good conduct’. [...] The integration of social research into CT development should be promoted through *Begleitforschung* (‘accompanying research’ science and technology R&D)” (ibid.:5).

ject(s). In the European CTEKS approach, the goals and problems to be solved are not considered as simply given, but rather must be found and formulated. Problems, goals and starting points must be determined. Thus, the Nordmann report's CTEKS approach "always [entails] an element of agenda setting. Because of this, converging technologies are particularly open to the deliberate inclusion of public and policy concerns. Deliberate agenda-setting for CTs can therefore be used to advance strategic objectives such as the Lisbon Agenda" (Nordmann et al. 2004:4). The report uses the buzzword "converging technologies" in the context of a future discourse which aims to determine research and development goals. Discursive, deliberative processes – connected with key words such as *participatory governance* and *technoscientific citizenship* – are favoured; a proximity to discourse ethics becomes apparent. The Nordmann report calls for an integration, not just of experts, but of citizens and concerned parties into the process of *agenda-setting*: "CTEKS agenda-setting is not top-down but integrated into the creative technology development process. Beginning with scientific interest and technological expertise it works from the inside out in close collaboration with the social and human sciences and multiple stakeholders through the proposed WiCCinitiative ('Widening the Circles of Convergence'). For the same reason, ethical and social considerations are not external and purely reactive but through the proposed EuroSpecs process bring awareness to CT research and development" (Nordmann et al. 2004:4). The normativity associated with that which appears on various levels – from basic persuasions to problem perceptions and definitions all the way to the definition of purposes and the formulation of goals – is made explicitly by the CTEKS approach, as part of ID: "Normative setting" is at the core of "interdisciplinary excellence" (Nordmann et al. 2004:42). To achieve this, the following is valid: "CTEKS research programs require and produce new standards for interdisciplinary research. Interdisciplinarity usually means that researchers from various disciplines pool intellectual and technical resources as they address a problem together. This form of interdisciplinarity is insufficient when the CTEKS agenda-setting process requires critical and comparative assessments of the viability of proposals. Mutual criticism across disciplinary boundaries is required [...]. Funding incentives for collaborative research is not enough to produce this kind of interdisciplinarity" (Nordmann et al. 2004:46).

Thus the Nordmann report fervently advocates a type of ID which we called *problem-oriented ID* in this paper.³³ Problems are at the centre,—they form the starting point for research programmes as well as projects. "It envisions that various European converging technologies research programs will be formulated, each addressing a different problem and each bringing together different technologies and technology-enabling sciences." (Nordmann et al. 2004:4) Thus the Nordmann report switches perspectives, away from an object-oriented ID, towards a problem-oriented ID, aiming for a convergence of goals and a critical reflection and revision of purposes.

8. Summary and prospects

If one takes what we have outlined above on problem-oriented ID as well as the other three types of ID (section 2) as a demarcating foil, then leading differences for the specification of this problem-oriented type of ID are as follows:

Problem-orientation versus *technology-induced approach (against object-oriented ID)*: Problem-oriented ID not only refers to technology, but is much more comprehensive. Jürgen Mittelstraß stresses: "While the technology-induced approach ties in with technology types in a product-oriented way, an analysing and assessing their consequences, the problem-oriented approach instead ties in with existing and foreseeable problems and technology defi-

³³ By widening the circles the CTEKS approach wishes to overcome what Segerstrale has severely criticized: "the missing discourse about science and society" (Segerstrale 2000).

cits. However, different from the technology-induced approach, the problem-oriented approach is not reactive; it is not just about technology-induced problems.” (Mittelstraß 1992:26) From this, criteria of anticipation have been deducted, along with earliness, *upstream engagement*, as well as outcome-orientation. Concerning the technology-induced approach, Niklas Luhmann has critically remarked that in this instance ”solutions to problems are seeking problems which they have solved in order to find their own meaning.” (Luhmann 1998:794) We can therefore draw a clear line between problem-oriented ID and the object-oriented ID that is most predominant in engineering sciences.

Problem-orientation versus a fixation on theory, concepts and fundamentals (contrary to theory-oriented ID): Theories, concepts and fundamentals may serve as means—however, their achievement is not a goal. “Problem-oriented research [must] be differentiated from fundamental research. [... it] focuses on problems which occur in the societal realm, while fundamental research, whose model is knowledge as an end in itself, does not answer to any other stimulant than that of research itself.” (Bechmann/Frederichs 1996:17) “Problem-oriented research cannot wait until the fundamentals of this area are clarified in order to then collect data and give advice based on well-established theories.” (Bechmann/Frederichs 1996:17) The traditional dichotomy of theory vs. practice appears in a modified manner. The connection with the project is made explicitly in contrast to the connection to the (research) program. Thus, there is a difference between problem orientation and focusing on basic research and theory and, consequently, between problem-oriented ID and theory-oriented ID.

Problem-orientation versus method constraints (contrary to method-oriented ID): This leading difference has been introduced to the ID debate under the title "Problem-orientation without method constraint" (Jäger/Scheringer 1998). Although methods may play a role in problem-oriented ID, for example in the concept of Rationalist Technology Assessment, this is only from the perspective of selecting means and adequate instruments. *Anything goes*—if it serves for the solving of problems. Developing methods is not an orienting goal of problem-oriented ID. However, the question of methodological foundation is highly disputed throughout the discourse on ID. Efforts are being made on various levels to carry out a methodolization of problem-oriented research by developing integration methods.

These three leading differences can be brought together in the above-discussed leading difference between science and society.³⁴ The difference also becomes evident when one keeps in mind that disciplinary science usually pursues (research) *programmes*, while problem-oriented ID conducts *projects*. In these projects the central task is not to solve but to clarify the problem and back-translate that which makes a problem a problem: the scientifically generated problem knowledge can be seen as a contribution to societal instructional knowledge. To speak of problem-orientation is, in a sense, more modest than to speak of solving a problem. Problem-orientation does not fall for the deceptive illusion that problems—once they have become dominant—are terminally solvable.³⁵ Even Karl R. Popper has pointed out a regress: “Every solution to a problem creates new unsolved problems.” (Popper 2000:42) Thus, Walther Rathenau was certainly right when he remarked: “The invention of the problem is more important than the invention of the solution.” Erich Jantsch even intensifies this idea: transdisciplinarity, he speculates, is “not for problem-solving, but for a continuous process of profound self-renewal.” (Jantsch 1972:102) According to Jantsch, at the core of ID is not a conclusive solution but rather an ever-present thorn in the flesh of society.

Not everyone will consider all of the four types of ID described above as relevant or acknowledge them as independent from each other. This is not surprising. The preference for each notion of ID depends upon the respective basic philosophical convictions. They determine

³⁴ Because, according to Dewey, problems and "uncertainty are first of all a practical matter" (Dewey 2001:223).

³⁵ According to Becker and Jahn it is “an illusionary yet prevalent view that implementing solutions intended as answers to problems makes those problems disappear. Rather, in most cases one given problem is transferred to another – hopefully better – condition, which itself, contains a (new) problem core” (Becker/Jahn 2006:312).

which type is considered central and which other types appear as consequences. With regard to well-established positions in the philosophy, we may state in an oversimplification: (a) *Realists* refer mainly to given *or* constructed objects of a human-independent reality (“ontological” dimension of ID). (b) *Rationalists* focus primarily on knowledge, theories, concepts, propositions, and on issues of justification of knowledge; positivists and some realists, e.g., structural realists, share the same orientation towards theories (epistemological dimension). (c) *Methodological constructivists*³⁶ and most *pragmatists* reflect on methods, on actions, or on cognitive rules (methodological dimension). (d) And *instrumentalists*, *utilitarians*, *critical theorists* and some other *pragmatists* refer to problems and problem perception, and how to handle and solve problems pragmatically; the impact, effect, and outcome of knowledge is of utmost relevance (problem-oriented dimension).

Hence, different philosophical positions determine (and give substance to) the different meanings of “ID”. Insofar as such philosophical positions *do* coexist, the various understandings of “ID” are nevertheless not at all reducible to a single one:³⁷ The debates surrounding the philosophy also make this point clear; taking the plurality of traditions in the philosophy of science into account, it is impossible to eliminate the plurality of ID” and achieve unification towards one semantic core.³⁸

The objective of this paper was to elaborate on the vague notion of problem in order to give some substance to a specific type of ID—namely to problem-oriented ID. It was meant to show that the notion of the problem is central to the discourse about ID. In view of this relevance in present-day science and research, the “problem” has, however, not received sufficient attention and reflection: we have problems with problems—with the reflection and revision of the starting points of concrete projects. Perhaps Ludwig Wittgenstein was right when he said: “A problem takes the shape of ‘I know nothing about this issue.’” (Wittgenstein 1999:302; PU, §123) That is probably also true for the “problem” itself, for problem perception, constitution and transfer: we know nothing about it—yet!

References

- Bechmann, G., Frederichs, G., 1996: Problemorientierte Forschung. Zwischen Politik und Wissenschaft. In: Bechmann, G. (eds.), 1996: Praxisfelder der Technikfolgenforschung. Campus, Frankfurt, pp. 11-37
- Becker, E., Jahn, T. (Hg.), 2006: Soziale Ökologie. Grundzüge einer Wissenschaft von den gesellschaftlichen Naturverhältnissen. Campus, Frankfurt
- Benyus, J.M., 2002: Biomimicry: Innovation Inspired by Nature. HarperCollins, New York
- Bergmann, M. et al., 2010: Methoden transdisziplinärer Forschung. Ein Überblick mit Anwendungsbeispielen. Campus, Frankfurt
- Bogner, A., Kastenhofer, K., Torgersen, H. (Hg.), 2010: Inter- und Transdisziplinarität im Wandel? Neue Perspektiven auf problemorientierte Forschung und Politikberatung. Nomos, Baden-Baden
- Böhme, G., van den Daele, W., Hohlfeld, R., 1978: Finalisierung revisited; In: Böhme, G. et al., 1978: Die gesellschaftliche Orientierung des wissenschaftlichen Fortschritts. Suhrkamp, Frankfurt, pp. 69-130
- Böhme, G., van den Daele, W., Krohn, W. (1974) Die Finalisierung der Wissenschaft, in: Diederich, W. (Ed) (1974) Theorien der Wissenschaftsgeschichte. Suhrkamp, Frankfurt, pp. 276f
- Chubin, S., Porter, A.L., Rossini, F.A., Connolly, T. (eds.), 1986: Interdisciplinary Analysis and Research. Theory and Practice of Problem-Focused Research and Development. Mt Airy, MD, Lomond

³⁶ This well-known position in German speaking countries is not adequately recognized by the international community of philosophy of science (cf. Janich 1992).

³⁷ This depends again on the philosophical background influencing one’s stance: most pragmatists (in the tradition of C.S. Peirce) and methodological constructivists (in the tradition of H. Dingler and P. Lorenzen) would argue that objects, knowledge, and problems/solutions are a mere consequence of methods. Reality is deducible from methods. They believe that methods constitute objects, knowledge and problems/solutions. They would reduce ID to method-oriented ID.

³⁸ Science—both disciplinary and interdisciplinary—is and will remain a multi-faceted phenomenon. Thus the ID discourse can simultaneously be perceived as an introduction to and an explication of philosophy of science positions.

- Decker, M. (ed.), 2001: *Interdisciplinarity in Technology Assessment. Implementation and its Chances and Limits*. Springer, Berlin.
- Decker, M., 2007: *Angewandte interdisziplinäre Forschung in der Technikfolgenabschätzung*. Schriftenreihe der Europäischen Akademie, Bad Neuenahr-Ahrweiler
- Decker, M., 2010: *Interdisziplinäre Wissensgenerierung in der TA – eine Prozessbeschreibung*; In: Bogner, A., Kastenhofer, K., Torgersen, H. (Hg.), 2010: *Inter- und Transdisziplinarität im Wandel? Neue Perspektiven auf problemorientierte Forschung und Politikberatung*. Nomos, Baden-Baden, pp. 145-165
- Dewey, J., 2001: *Die Suche nach Gewißheit*. Suhrkamp, Frankfurt
- Dörner, D., 1995: *Die Logik des Mißlingens. Strategisches Denken in komplexen Situationen*. Rowohlt, Hamburg
- Fagerberg, J., 2005: *Innovation – A guide to the literature*; In: Fagerberg, J., Mowery, D.C., Nelson, R.R. (eds.), 2005: *The Oxford Handbook of Innovation*. Oxford University Press, Oxford, pp. 1-26
- Feynman, R.E., 1959/2003: *There's Plenty of Room at the Bottom*; In: <http://www.zyvex.com/nanotech/Feynman.html>
- Frodeman, R., Thompson Klein, J., Mitcham, C. (eds.), 2010: *The Oxford Handbook of Interdisciplinarity*. Oxford Uni Press, Oxford/New York
- Gethmann, C.F., 1999: *Rationale Technikfolgenbeurteilung*; In: Grunwald, A. (Hg), 1999: *Rationale Technikfolgenbeurteilung. Konzepte und methodische Grundlagen*. Springer, Berlin, pp. 1-10
- Gibbons, M. et al., 1994: *The New Production of Knowledge*. Sage, London
- Gieryn, T.F., 1983: *Boundary work and the demarcation of science from non-science. Strains and interests of professional ideologies of scientists*; In: *American Sociological Review* 48, pp. 781-795
- Grunwald, A. (Hg), 1999: *Rationale Technikfolgenbeurteilung. Konzepte und methodische Grundlagen*. Springer, Berlin
- Grunwald, A., 2002: *Technikfolgenabschätzung. Eine Einführung*. Edition Sigma, Berlin
- Grunwald, A., 2007: *Auf dem Weg zu einer Theorie der Technikfolgenabschätzung: der Einstieg*; In: *Technikfolgenabschätzung. Theorie und Praxis* Nr. 1, 16. Jg., März 2007, pp. 4-17.
- Habermas, J., 1970: *Erkenntnis und Interessen*. Suhrkamp, Frankfurt
- Hacking, I. 1983: *Representing and intervening introductory topics in the philosophy of natural science*. Cambridge University Press, New York
- Haken, H., 1980: *Dynamics of Synergetic Systems*; Berlin, Springer.
- Harris, C.E., Pritchard, M.S., Rabins, M.J., 2005: *Engineering Ethics. Concepts and Cases*; third edition, Thomson Wadsworth, Belmont/CA.
- Hentig, H. v., 1972: *Magier oder Magister? Über die Einheit der Wissenschaft im Verständigungsprozeß*. Klett, Stuttgart
- Hoffmann, M.H.G., 2010: *Analyzing Framing Processes in Conflicts and Communication by Means of Logical Argument Mapping*; In: Donohue, B., Kaufman, S., Rogan, R. (eds.), 2010: *Framing in Negotiation: State of the Art*; (in press).
- Janich, P. (ed.), 1992: *Entwicklungen der methodischen Philosophie*. Suhrkamp, Frankfurt
- Jantsch, E., 1972: *Towards Interdisciplinarity and Transdisciplinarity in Education and Innovation*; CERI, Interdisciplinarity, Paris (identical: *Inter- and Transdisziplinarität University: A Systems Approach to Education and Innovation*; *Policy Sciences* 1, 1970, pp. 403-428)
- Jaeger, J., Scheringer, M., 1998: *Transdisziplinarität. Problemorientierung ohne Methodenzwang*, in: *GAIA* 7/1:10-25
- Jungert, M., et al. (eds.), 2010: *Interdisziplinarität. Theorie, Praxis, Probleme*. WBG, Darmstadt
- Kline, S.J., 1995: *Conceptual Foundations of Multidisciplinary Thinking*. Stanford University Press, Stanford
- Kastenhofer, K., 2010: *Zwischen „schwacher“ und „starker“ Interdisziplinarität: Sicherheitsforschung zu neuen Technologien*; In: Bogner, A., Kastenhofer, K., Torgersen, H. (eds.), 2010: *Inter- und Transdisziplinarität im Wandel? Neue Perspektiven auf problemorientierte Forschung und Politikberatung*. Nomos, Baden-Baden, pp. 87-122.
- Krohn, W., 2010: *Interdisciplinary Cases and Disciplinary Knowledge*; In: Frodeman, R. et al. (eds.), 2010: *The Oxford Handbook of Interdisciplinarity*. Oxford Uni Press, New York/Oxford, pp. 32-49
- Kuhn, T.S., 1996: *Die Struktur wissenschaftlicher Revolution*. Suhrkamp, Frankfurt
- Kuhn, T.S., 1997: *Die Entstehung des Neuen*. Suhrkamp, Frankfurt
- Latour, B., Woolgar, S., 1979: *Laboratory Life*. Princeton University Press, Princeton/NJ
- Liebert, W., Schmidt, J.C., 2010a: *Collingridge's dilemma and technoscience. An attempt to provide a clarification from the perspective of philosophy of science*; In: *Praxis & Poiesis* 7(1-2), pp 55-71
- Liebert, W., Schmidt, J.C., 2010b: *Towards of prospective technology assessment. Challenges for technology assessment (TA) in the age of technoscience (with W. Liebert)*; In: *Praxis & Poiesis* 7(1-2), pp. 99-116
- Mainzer, K., 1996: *Thinking in complexity. The complex dynamics of matter, mind, and mankind*. Heidelberg
- Mantegna, R.N., Stanley, H.E., 2000: *An Introduction to Econophysics: Correlations and Complexity in Finance*. Cambridge University Press, Cambridge

- Mittelstraß, J., 1987: Die Stunde der Interdisziplinarität? In: Kocka, J. (ed.): Interdisziplinarität. Praxis, Herausforderung, Ideologie. Suhrkamp, Frankfurt, pp. 152-158
- Mittelstraß, J., 1992: Leonardo-Welt. Über Wissenschaft, Forschung und Verantwortung. Suhrkamp, Frankfurt
- Mittelstraß, J., 1998: Die Häuser des Wissens. Suhrkamp, Frankfurt
- Mittelstraß, J., 2005: Methodische Transdisziplinarität; In: Technikfolgenabschätzung. Theorie und Praxis, 14(2), pp. 18-23
- Nersessian, N., 2008: Creating Scientific Concepts. MIT Press, Cambridge/MA.
- Nordmann, A., 2004: Was ist TechnoWissenschaft? Zum Wandel der Wissenschaftskultur am Beispiel von Nanoforschung und Bionik, in: Rossman, T., Tropea, C. (eds.), 2004: Bionik: Aktuelle Forschungsergebnisse in Natur-, Ingenieur- und Geisteswissenschaften. Springer, Berlin, 209-218
- Nordmann, A., et al., 2004: High Level Expert Group "Foresighting the New Technology Wave": Converging Technologies – Shaping the Future of European Societies; European Commission, Bruxelles (ftp://ftp.cordis.lu/pub/foresight/docs/ntw_report_nordmann_final_en.pdf)
- Norton, B.G., 2005: Sustainability. A Philosophy of Adaptive Ecosystem Management.; University of Chicago Press, Chicago/London
- Pohl, C., Hirsch Hadorn, G., 2006: Gestaltungsprinzipien für die transdisziplinäre Forschung. Oekom, München
- Popper, K.R., 2000: Vermutungen und Widerlegungen. Mohr Siebeck, Tübingen
- Rickert, H., 1986: Kulturwissenschaft und Naturwissenschaft. Reclam, Stuttgart
- Roco, M.C., Bainbridge, W.S. (eds.), 2002: Converging Technologies for Improving Human Performance. Nanotechnology, Biotechnology, Information Technology and Cognitive Science; National Science Foundation, Arlington/Virginia
- Ropohl, G., 2002: Rationalität und Allgemeine Systemtheorie. Ein Weg synthetischer Rationalität. In: Karafyllis N., Schmidt J.C. (eds.), 2002: Zugänge zur Rationalität der Zukunft. Metzler, Stuttgart, pp. 113-137
- Ropohl, G., 2005: Allgemeine Systemtheorie als transdisziplinäre Integrationsmethode; In: Technikfolgenabschätzung. Theorie und Praxis, 14(2), 24-31
- Schmidt, J.C., 2002: Interdisziplinäre Erkenntniswege. Versuch einer wissenschaftsphilosophischen Charakterisierung; In: Krebs, H. et al. (eds.), 2000: Perspektiven Interdisziplinärer Technikforschung. Konzepte, Analysen, Erfahrungen; Münster, 55-72
- Schmidt, J.C., 2003: Wundstelle der Wissenschaft. Wege durch den Dschungel der Interdisziplinarität; In: Scheidewege, 33, 169-189
- Schmidt, J.C., 2004: Unbounded Technologies. Working Through the Technological Reductionism of Nanotechnology", In: Baird, D. et al. (eds.), 2004: Discovering the Nanoscale. AOS, Amsterdam, pp. 35-51
- Schmidt, J.C., 2005: Dimensionen der Interdisziplinarität. Wege zu einer Wissenschaftstheorie der Interdisziplinarität; In: Technikfolgenabschätzung. Theorie und Praxis, 14(2), 12-17
- Schmidt, J.C., 2007a: Towards a Philosophy of Interdisciplinarity. An attempt to Provide a Classification and Clarification; In: Praxis & Poiesis 5(1), 53-71
- Schmidt, J.C., 2007b: Knowledge Politics of Interdisciplinarity. Specifying the Type of Interdisciplinarity in NSF's NBIC Scenario; In: Innovation. European Journal of Social Science Research 20(4), 313-328
- Schmidt, Jan C., 2008: Instabilität in Natur und Wissenschaft. Eine Wissenschaftsphilosophie der nachmodernen Physik. De Gruyter, Berlin
- Schmidt, J.C., 2010: Prospects for a Philosophy of Interdisciplinarity; In: Frodeman, R., Thompson Klein, J., Mitcham, C. (eds.), 2010: The Oxford Handbook of Interdisciplinarity; Oxford Uni Press, Oxford/New York, pp. 39-42.
- Scholz, R. W., 2011: Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge: Cambridge University Press.
- Seegerstrale, U. (ed.), 2000: Beyond science wars: The missing discourse about science and society. State University of New York Press, New York
- Stix, G., 2001: Little Big Science; Scientific American, 9, pp. 32ff
- Thompson Klein, J., 1990: Interdisciplinarity: History, Theory, and Practice.; Wayne State University Press, Detroit
- Thompson Klein, J., 1996: Crossing Boundaries: Knowledge, Disciplinarity, and Interdisciplinarity. University Press of Virginia, Charlottesville
- Thompson Klein, J., Grossenbacher-Mansuy, W., Häberli, R., Bill, A., Scholz, R.W., Welti, M. (eds.), 2001: Transdisciplinarity: Joint problem solving among science, technology, and society. An effective way for managing complexity. Birkhäuser, Basel
- Weinberg, A.M., 1972: Science and Trans-Science; In: Minerva, 10(2), 209-222.
- Weingart, P., Stehr, N. (eds.), 2000: Practising Interdisciplinarity. University of Toronto Press, Toronto
- Weizsäcker, C.F. v., 1974: Die Einheit der Natur. Dtv, München
- Wittgenstein, L., 1999: Werksausgabe, Bd. 1 (Tractatus, Philosophische Untersuchungen, u.a.). Suhrkamp, Frankfurt
- Wright, G.H. v., 1991: Erklären und Verstehen. Hain, Meisenheim
- Wolters, G., 2004: Problem; In: Enzyklopädie für Philosophie und Wissenschaftstheorie, Bd. 3., pp. 347-348.