Knowledge Politics of Nano-Interdisciplinarity

Towards a Critical Knowledge Assessment

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***Abstract*–In late-modern societies, knowledge constitutes a major component of any human activity. Knowledge politics—a field of political activities concerned with the production, application, monitoring and control of new knowledge and knowledge-based technoscientific innovations—has gained importance over the last 30 years. A central term in recent knowledge politics is "interdisciplinarity". The vagueness of this term, however, appears to be a disadvantage for any public discourse on goals and objectives of any specific knowledge politics. In addition to what has been achieved in the field of reflection on interdisciplinarity (ID), the aim of this paper is to provide a philosophical foundation for a classification *and* criticism of the innumerable usages of interdisciplinarity in present knowledge politics. With regard to established positions in the philosophy of science, different types of ID can be distinguished: the object type ("ontology"), the theory type (epistemology), the method type (methodology), and the problem / purpose type. Based on this classification I will show which specific type of ID is involved in the NSF's scenario on converging technologies—one of the most prominent kinds of knowledge politics. This type of interdisciplinarity will be contrasted with the research program of the European Commission on converging technologies.**

Introduction: The late-modern Shift from Technology to Knowledge

A few decades ago, a well-known and widely-discussed question was: *do artifacts have politics*? [1] Nowadays, since hybrids, quasi-objects, and non-human beings are populating and conquering our life-world—also, posing challenges to any kind of governance and public policy—, Langdon Winner's position is taken for granted. Artifacts carry inherently political qualities; they change social-cultural norms, diversify political actions, and in particular, revise the conditions of the possibility of politics. In this sense, artifacts are comparable to any other kind of political actions, norms, regulations and laws—but with much more far ranging impact on the life-world. In fact, the development and diffusion of technical artifacts can be regarded as a materialization of politics, e.g. of political decisions on various levels and in different kinds of institutional seetings. The various notions of (global and local) *governance* reflect the diversification of politics. Not only technology changes politics, and politics influences technology, but technology has to be considered as a type of politics!

Over the last 30 years, however, the pace of the *scien-technological* development has being accelerated. The material signs and symbols of technical artifacts are vanishing. Non-materialized technologies, such as information and communication technologies, grow rapidly. Marc Weisser emphasizes that, "the most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." Indeed, we can observe a paradigm shift in the sociotechnological sphere: from materialized technologies to non-materialized knowledge. The more technology conquers our life-world and the broader technology regulates our late-modern societies, the less we perceive it.

A late-modern question would be: *does knowledge have politics?* While science (research) and technology (development) politics has been around since the time of Francis Bacon in the early 17th century, today *knowledge* politic [2] is a central field of political activity that has gained importance during the last 30 years. The challenge is obvious: Knowledge has to be shaped—in particular, it has to be regulated and restricted, fostered and funded, created and constructed. Guidelines and criteria have to be developed. An unrestricted or instantaneous production, diffusion and use of new knowledge is no longer feasible—if it ever was. Side-, long-term and accumulative effects have to be taken into account. Risks have to be identified and public debates about risks have to be induced, monitored and moderated. Path decisions about which knowledge is desirable and acceptable have to be made as early as possible. Late modern societies are—according to Ulrich Beck's *Reflexive Modernization* theory— reflexive in the sense that we are faced with problems induced by the rapid development and distribution of technologies [3]. In order to cope with pressing problems, a need for new and better knowledge is emerging.

Thus, knowledge politics and knowledge assessment seem to be more fundamental and far reaching than traditional science and technology politics: knowledge enables developments in science and technology within society;

knowledge underlies and determines the whole innovation process. The relevance of knowledge regulation for shaping the future of societies seems to be evident: Knowledge politics normatively defines and assesses the specific type of knowledge that seems to be most important for the future of society. It regulates and determines the future trajectories of the development of late-modern society. *Shaping knowledge is* (a central element for) *building society!* Knowledge politics is, of course, a product of the technological development itself. Ambivalent side effects have become obvious; the development of new technologies has turned out to be far more complex than in the past, e.g. time-consuming, risky, expensive, sensitive dependent on government regulation and funding. And, in addition, learning to manage non-knowledge poses challenges to late-modern societies.

A core term of current knowledge politics seems to be "interdisciplinarity" [4]. "Interdisciplinarity" is an eminently political term, also revealing that science has become reflexive and is rapidly changing. While disciplinary knowledge seems to be of limited utility—pressing real-world problems do not fit into the established framework of disciplinary fragmentation—interdisciplinarity seems to be a way out in order to cope with misty real-world problems of our societies. A *new mode of knowledge production* seems to be indispensable [5]. Post-industrial and late-modern knowledge societies [6] demand interdisciplinarity in order to facilitate knowledge production and processing and to ensure international competitiveness and customer care. In other words, interdisciplinarity is highly valued from various perspectives. Thus, interdisciplinarity seems to be a marker not only to characterize recent sciences, but to describe societal-cultural changes. Obviously, late-modern knowledge societies require interdisciplinarity whereas classical-modern industrial societies mainly attempt to promote disciplinarity: in fact, late-modernity could be characterized by interdisciplinarity (and knowledge politics), modernity by disciplinarity (and technology politics).

Let us illustrate this thesis in more detail. A prominent example for present-day *knowledge politics of interdisciplinarity (for short: ID)* is given by the U.S.-National Science Foundation (NSF). The NSF refers to ID, namely the integration and convergence of nanotechnology, biotechnology, information technology and cognitive science (NBIC) [7]. Here, ID should guarantee technological innovation by a "synergistic combination of four major 'NBIC'." The main question addressed in this paper is whether we can legitimately label the NBIC vision "interdisciplinary". The question is not easy to answer because "ID" appears to be a vague term. In this paper I will try to clarify the meaning*s* of and contribute to the expanding discourse on inter- and transdisciplinarity in present-day knowledge politics. Referring to well-established distinctions in the philosophy of sciences and technology, this paper argues in favor of a plurality of four different types that specify related but distinguishable meanings: ID with regard to (a) concepts/theories (epistemology), (b) methods/practices (methodology), (b) objects (ontology), and further, (d) purpose setting/problem framing/problem solving. By this categorization, I will critically clarify and assess the specific type of ID that is involved in the NBIC scenario. I will deconstruct and assess the knowledge politics by analytic clarification in order to enable a stimulating of a public discourse.

Now, in the following, I sketch some ideas of the NSF's NBIC report (next paragraph). By referring to well-established distinctions in the philosophy of sciences I will propose a classification scheme of four different types of ID. – Next I will show that the NSF's knowledge politics is based on object-ID, more specifically as techno-object ID which advocates a technologically related reductionism. – Then, the techno-object ID of the NSF's knowledge politics will be compared and contrasted with an explicit normative approach, the problem-oriented ID of the European Commission initiative on converging technologies (CTEKS). – I will conclude that a critical reflection on and revision of goals and purposes should guide the knowledge politics towards our common future.

1. CONVERGING TECHNOLOGIES …

In the classic report on "Converging Technologies" the U.S.-National Science Foundation (NSF) aims to advocate a specific type of ID [8]. Let us analysis this in more detail.

ID appears to be the key element in the NSF's NBIC vision to combine, converge and unify the engineering and natural sciences. The focus of the NSF is on engineering sciences and on a science-based technological shaping of the world—including the human body. The NSF begins the report by analyzing the deficits of engineering sciences. Hitherto, engineering sciences largely form a patchwork of very different areas such as civil, electrical, mechanical, material, informational, and medical engineering. In consequence, classical technologies are bounded technologies that are applied in specific contexts, e.g., biomedical technologies in the field of medicine or information technologies in the context of information processing, management and storage. Specialization has splintered engineering sciences. None of the disciplines can master more than a tiny isolated fragment of all problems. Over the last 60 years, efforts have been made to bring together the various parts of science-based technologies—e.g., the earlier attempts of cybernetics in the 1940's such as general systems theory, information theory, solid-state physics; and also micro systems technology in the 1970s and 1980s.

There has been, however, little overall progress until now. Engineering sciences remain a patchwork. In fact, disciplinary and subdisciplinary boundaries between engineering sciences restrict the pace of invention and innovation. Boundaries limit the development of new methods and new technologies. "The traditional tool kit of engineering methods will be of limited utility in some of the most important areas of technological convergence." [9] The NSF aims to overcome the apparent limitation of traditional engineering methods by seeking a common technoscientific fundament assumed to underlay all the engineering sciences. *Technoscience* is an ideal term to highlight the merging of engineering sciences, natural science and technology. Such a deeper fundament should help to transgress the boundaries between the various engineering sciences and between engineering and natural sciences and, thus, it should foster inventions and innovations. The NSF's vision can be interpreted as an attempt to facilitate a foundation of engineering sciences on a deeper level similar to the foundation of physics and the unification project. Such a fundament, which can be called "enabling technologies" [10] will have enormous power for technological development in general. Enabling technologies are thought to be rooted at a deeper level; enabling technologies are basic, fundament, and mother technologies that create, construct, and foster particular technologies in applied branches.

ID is interlaced with unity metaphysics. The NSF explicitly highlights the need for "unifying science and converging technologies" in order to "improve human performance" [11]. From a philosophical point of view, it is surprising that the NSF's vision seems to be rooted in a very traditional metaphysical claim regarding a "unity of nature" that reveals a strong naturalism. "In the early decades of the 21st century, concentrated efforts can unify science based on the unity of nature, thereby advancing the combination of nanotechnology, biotechnology, information technology, and new technologies based on cognitive sciences." [12] Although the NSF report does not define "unity of nature"—it just mentions the "unified cause-and-effect understanding of the physical world" (ibid)—the unity seems to provide a reason *why* a unification of science is possible and *why* an advancement of technoscience is feasible.

ID, unity, and synergism are often used interchangeably. The NSF report follows this common understanding. ID means a "unification of sciences" and a "synergistic combination" of technologies. "The phrase 'convergent technologies' refers to the synergistic combination of four major 'NBIC' (nano-bio-info-cogno) provinces of science and technology, each of which is currently progressing at a rapid rate." [13] Interchangeable with "ID", the term "synergetic" is one of the most popular terms in contemporary knowledge politics. Coined by the physicist Hermann Haken in the late 1960s, the term has become tremendously popular. According to Haken, the main principle of synergetics is the "enslavement principle" as it occurs in the creation of a laser beam. Due to small differences in initiate conditions caused by fluctuations, one mode will become the "master" that "enslaves all other modes". Consequently, just a few order parameters are sufficient to describe a complex system such as a laser.

"Unity" means here that many variables of the complex system can be reduced to a few order parameters. According to these considerations, in NSF's understanding of "converging technologies" *one* technology enslaves the others. The symmetry of four NBIC technologies is broken. One technology turns out to be the dominant master. Nanotechnology seems to be *the* fundamental basis for the unification of technologies. The abstract nanoscale and the material nanoobjects are the locus where the convergence of the four technologies is supposed to take place: "Convergence of diverse technologies is based on material unity at nanoscale and on technological integration from that scale. The building blocks of matter that are fundamental to all sciences originate at nanoscale." [14] Nanoobjects are at the center of the synergistic unification. Everything seems to converge into the very small and abstract world of the nanocosm.

Convergence is not the final result but a process. It is the pacemaker to unity; unity is the final point, which is the point of total control, something like Archimedes' "place to stand on" to "move the Earth". Convergence means a convergence of technosciences to nanotechnology and of technological artifacts to nanotechnological artifacts. The metaphor of "convergence" is related to catchwords such as "holistic view" and "holism". "Converging of the sciences can initiate a new renaissance, embodying a holistic view of technology based on transformative tools, the mathematics of complex systems, and unified cause-and-effect understanding of the physical world from the nanoscale to the planetary scale." [15] Here, the NSF report renews the traditional metaphysical view of continuous causality and a causal nature in order to open up a new (old) horizon of technoscientifc possibilities. The vision of the NSF report also involves social sciences and humanities. The NSF believes in the possibility "to develop a predictive science of society." [16] ID in this broad sense does not only encompass natural and engineering sciences but all disciplines. "A trend towards unifying knowledge by combining natural sciences, social sciences, and humanities using cause-and-effect explanation has already begun." [17] Social systems and human behavior seem to be explainable by causality. What works in the domain of nature is presupposed to work in the domain of social systems too.

The NSF report also assumes that nanobased technologies will change society positively and dramatically. "Converging technologies could achieve a tremendous improvement in human abilities, societal outcomes, the nation's productivity, and the quality of life." [18] A "new renaissance" and a "next industrial revolution" will emerge. This optimism seems to be at the core of the knowledge politics of the NSF's NBIC advocates. As the classical renaissance period was, indeed, a technologically driven transition phase between the medieval times and the modern times, such a talk about a "new renaissance" equates any science-based technological progress with human and societal progress. The NSF report does not seem to be too far away from the idea of "modernity" that was developed in the 17th century. NSF's vision, therefore, is neither unique nor novel. It can be traced back to the politician and philosopher Francis Bacon and the optimism of his contemporaries.

The NSF's paradigm on converging technologies is nothing less than a renaissance of classical *reductionism*. Although there is no longer the intention to reduce everything to physics, or chemistry, we can identify a sort of "neutral (non- or inter-disciplinary) reductionism". The NSF states: "Some partisans for independence of biology, psychology, and the social sciences have argued against 'reductionism', asserting that their fields had discovered autonomous truths that should not be reduced to the laws of other sciences. But such a discipline-centric outlook is self-defeating, because as this report makes clear, through recognizing their connections with each other, all the sciences can progress more effectively." [19]

For opening Pandora's Box of ID knowledge politics, a critical reflection on knowledge, methods, objects, and problems is indispensable; contents and contexts are important to consider.

2. Different Notions of ID

Nearly all who speak of "interdisciplinarity" (ID) in scientific or public debates are pursuing goals. They do not aim only to describe science. Rather, they intend to change, to renew and to re-structure sciences, and to shape science-based technologies and societies. Referring to interdisciplinarity, Erich Jantsch advocated the "self-renewal of society" [20] in the 1970s, today Jan Fagerberg stresses "innovation" and "long-term economic growth" [21]. Normativity is always involved. Interdisciplinarity does not aim to leave disciplines (and disciplinarity) unaffected and society untouched. An implicit societal theory—how to understand contemporary techno-scientific societies and how to shape the societal future—is always present when "interdisciplinarity" appears. Interdisciplinarity is an eminently political term: a core element of present-day "knowledge politics" [22].

A critical reflection on the way in which the NBIC advocates of the Roco-Bainbridge-report use the term "interdisciplinarity" should start with an analytical classification. In addition to what has been achieved in the field of reflection on interdisciplinarity, I will propose a classification framework of different types of interdisciplinarity [23]. A plurality of meanings will be shown, without a unifying semantic core. There is not *one* type of interdisciplinarity—and not *one* kind or one overall goal of interdisciplinary knowledge politics—but various types coexist.

Object ID: Entities or objects constitute the central elements of *object-interdisciplinarity* (ontological dimension of ID). The historically established functional differentiation into disciplines does not seem to be contingent. Rather, it mirrors aspects of the structure of reality. Edmund Husserl, Nicolai Hartmann, and Alfred North Whitehead argue in favor of a concept of layered reality. Boundaries between the layers separate the micro-, meso- and macrocosm. Interdisciplinary objects are thought to be located on boundaries between different cosms or within border zones between disciplines, for example, the brain-mind object. In order to substantiate this position one has to presuppose a minimal ontological realism, interlaced with a concept of layered reality, and, based on this, an ontological non-reductionism: Brain-mind objects can be reduced neither to the material brain nor to the mental mind but, perhaps, to other entities (neutral ontology). Old and ongoing philosophical issues about monism, dualism and pluralism emerge in this debate. ID here does not refer mainly to knowledge, methods or problems, but to an external, human-independent reality.

The foregoing position is a strong one. It might be called *universal object* ID. A weaker position—which can be named *real-constructivist* or *techno-object* ID—does not assert a timeless existence of interdisciplinary objects in an unchangeable reality but rather that interdisciplinary objects are created by human action. Examples include the hole in the ozone layer, or—as we will see later on in much more detail—techno-objects of nanoscience: nanoobjects are placed on the boundaries between physics, chemistry, biology, and engineering sciences. This ontological position is neither a classic cognitive-oriented realist's position nor a constructivist one: it can be called *real-constructivism* and it traces back to Bacon, and more recent, to Ian Hacking [24]. Unfortunately, however, real constructivism is not fully developed in philosophy of science.

Theory ID focuses on knowledge, theories, and concepts, and not primarily on objects and reality. It is concerned with whether interdisciplinary theories exist and how they may be specified. Can we demarcate interdisciplinary knowledge from disciplinary knowledge and from non-scientific knowledge? Is there a unique context of justification? Do interdisciplinary models, laws, descriptions, and explanations exist? Possible candidates for theory-ID are concepts which can be applied to describe objects in different disciplinary domains; they highlight structural similarities between properties of these objects. Such theories cannot be reduced to disciplinary ones. Theory-ID is, therefore, based on an epistemological non-reductionism.

Structural sciences such as complex systems theory are prominent examples [25], [26]. Structurally similar process phenomena—e.g., pattern formation, self organization, bifurcations, structure breaking, and catastrophes—can be found in different disciplinary branches. The objective is an integration of general structures regardless of the disciplinary content. Alike theories are self-organization theory, dissipative structures, synergetics, chaos theory, and fractal geometry. Hermann Haken regards synergetics as an "interdisciplinary theory of general interactions" [27]. Most of these interdisciplinary theories were established in the 1960s and 1970s. Basic ideas—and the term "structural sciences"—, however, can be found in works from the 1940s and 1950s. Structural sciences "study their objects regardless of disciplinary domains and in abstraction from disciplinary content" [28]. Classic examples are cybernetics, information theory or game theory.

Method ID refers to knowledge production, to research processes, to rule-based actions, and to languages. The central issue of methodology is *how,* and by *which rule,* can and should we obtain knowledge? In terms of interdisciplinarity, central questions are: Do interdisciplinary methods and actions exist? Is there a specific context of discovery within interdisciplinary projects? Interdisciplinary methodologies, however, are thought to be irreducible to a disciplinary methodology.

Biomimicry, for example—sometimes used interchangeably with bionics—claims to be an interdisciplinary *transfer methodology* from biology to engineering sciences [29]. The basic idea of biomimicry is "learning from nature" in order to "inspire technological innovations." Nature seems to provide excellent inventions that can be used to develop efficient technologies. However, the transfer is not a one-way street. Biomimicry constructs models of biological nature based on the perspective of engineering sciences. A robot mimics an ant, but at the same time the ant has been described from the mechanistic perspective of technology. Besides biomimicry, there are other examples of interdisciplinary methodologies. Econophysics methodologically organizes a transfer between physics and finance/economics [30].—In addition to these transfer methodologies, a new kind of non- or meta-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—, but they are also pragmatically used an developed to integrate knowledge from different disciplinary domains.

Problem- and purpose-oriented ID: We have to add another type that focuses on the starting points and goals, problems and purposes of research programs—in other words, the problem framing and agenda setting type. Erich Jantsch argues in favor of a "purposive level of interdisciplinarity" and a "purpose-oriented interdisciplinarity", today sometimes called "transdisciplinarity". An explicit reflection on, and revision of, purposes should be regarded as the highest level of interdisciplinarity [31]. Juergen Habermas draws attention to the aims in connection with the kick-off of a particular research program [32]. Normative premises, such as problem identifying and agenda setting, the volition or intention to obtain certain knowledge, precede both the context of discovery and the context of justification, i.e., the theories and the methods.

The very first step in scientific inquiry is often judged to be a contingent factor; the teleological structure in the process of knowledge production is not always acknowledged. In fact, philosophers of science have widely ignored problem identifying or agenda setting, although work has been done on "wicked problems". The lack of clarification is a disadvantage for specifying problem-oriented ID and demarcating it from disciplinarity. Obviously, interdisciplinary problems are external to disciplines and to sciences in general. They are primarily societal and are defined by society, e.g., lay people, politicians, and stakeholders. To contribute to societal problem solving and to ensure societal progress, disciplinary limitations have to be overcome. In this sense ID is seen as an instrument meeting societal demands in order to tackle pressing problems. Examples of problem-oriented ID are sustainability research, technology assessment, and social ecology [33].

One or other of the above-listed types of ID may raise concerns. Underlying philosophical convictions determine which type might be considered most important and which of the other types will just be viewed as mere inferences. Even in the new field of *knowledge politics*, (implicit) philosophical convictions play a role.

Regarding well-established positions in the philosophy of science, we can denote: (1) *Realists* and *real-constructivist* refer to given *or* constructed objects of reality (they prefer the ontological dimension of ID). (2) *Rationalists* focus on knowledge, theories, and concepts; *positivists* share the same orientation toward theories (epistemological dimension). (3) *Methodological constructivists* and many *pragmatists* reflect on methods, actions, or cognitive rules (methodological dimension). (4) *Critical theorists*, together with *instrumentalists*, *utilitarians* and some *pragmatists,* refer to problems and how to handle and solve problems pragmatically. The impact, effect, and consequence of ID are of utmost relevance (problem-oriented dimension).

The different approaches to interdisciplinarity depend on underlying philosophical convictions. We cannot eliminate this plurality. "ID" is, and will always be, a multifaceted term—open to any kind of political shaping. Philosophy of science is effectively helpful in analyzing and classifying interdisciplinarity.

3. Application of the ID-Framework and Knowledge Assessment

Now we are ready to address the question of which type of interdisciplinarity is most dominant in the Roco-Bainbridge-report: which kind of interdisciplinarity is the objective of this report? To state it plainly, the report does not have much to offer with regard to theories and methods, and it offers only marginal aspects with regard to problems and purposes.

Theory ID: A patchwork of models would work well if it provided a sufficient and an efficient basis for technological interventions. A coherent and consistent theory is not the aim of the Roco-Bainbridge-report and the NBIC scenario; 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. They are not in themselves superior to models. To put it briefly: technology is the aim, not theory; technological intervention instead of theoretical represention. – On the other hand, the Roco-Bainbridge-report realizes that theoretical elements are indispensable. 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." [34] Nothing turns out to be more practical than an adequate theory. In fact, the theoretical orientation for the sake of practical relevance makes the NBIC scenario an excellent example of a "technoscience" [35]. 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 talk about the integration of knowledge, models and concepts rather than about a theory. – In addition, let us look at theories from another perspective. Assume for the moment—contrary to what I have elaborated so far—that theories were the aim of the NBIC scenario. Then, let us ask: Are the NBIC-technologies successful? Not at all! It is hard to see any common theoretical umbrella or any interdisciplinary theory in the NBIC scenario—even if we refer to the weak understanding of theory. Certainly we find progress regarding theories within the branch of disciplinary (nano-) physics. But in the context of theories the progress of nanophysics can hardly be called "interdisciplinary".

Method ID: A common method and a unified methodology are not the aim of the Roco-Bainbridge-report. Methods are regarded as means and instruments to obtain knowledge. What matters most is the efficiency and the effectiveness of methods in general, 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 trace back to chemistry and molecular biology. A physicist, Richard Feynman, gave the first programmatic speech on nanotechnology in 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. For the rise of nanotechnology, new physical instruments such as the *scanning tunneling microscopy* (STM) and the *atomic force microscope* (AFM) are of major importance. They stem from advanced developments of physics in the early 1980's. If the core of the NBIC scenario is rooted in nanotechnology, then it is rooted in *disciplinary* physics, or in molecular biology.

Problem- and purpose-oriented ID: So, the NBIC-convergence can hardly be regarded as problem-oriented. It is mainly technoobject-oriented. Only very general and unspecific goals are formulated, such as such as human enhancement and fulfilling the basic needs of the LDC. The term "new renaissance" seems to be nothing but a metaphor. The general goals lack of very content. In contrast, problem-orientation means to deliberately set goals, reflect on 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 making use of and developing new technologies. The Roco-Bainbridge-report does not explicate or attempt to initiate a discourse about purposes. However, the report seems to be fascinated by the technological development in itself, interlaced with the unspecific idea of human enhancement: opening 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).

Object ID: Until now my findings have been negative—there is a lack of theory- and method-ID and a very limited, if any, problem-oriented ID. What can be said about object-ID? According to my definition in paragraph 3.1, we have to take two different kinds of object-interdisciplinary into account. (a) The *strong version* assumes objects to be time-invariantly located on boundaries due to the universal layers of reality (universal object-ID). Following the underlying ontological realism, these objects were called interdisciplinary objects. (b) A *weaker version* states that the boundaries have not existed and do not exist for ever (partial or realconstructivistic object-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 nanotechnological objects. They have not existed before and do not exist independently in Nature, 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 seem to be *the* fundamental basis for converging technologies. This is a convergence in objects, not in theories, methods, or problems. The scale of the nanotechnoobject is where the convergence of the four technologies is supposed to take place: "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." [36] In the very small and realconstructed world of the nanocosm, everything seems to converge. From this perspective, the nanotechnoobjects can be labeled "interdisciplinary". – It is interesting to see how the realconstructed 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 worthwhile to stress that "converging technologies" does not mean a convergence to objects that belong to disciplinary physics but rather a convergence to technoscientific nanoobjects—that are objects for technological purposes. This is why we do not have a reduction to disciplinary objects such as objects of physics in the NBIC scenario, but a reduction to interdisciplinary (realconstructed) objects. In this sense, nanotechnoojects are located between physics, chemistry, biology, and some engineering sciences. Here, Richard Feynman, the early protagonist of nanotechnology, identified that "There is plenty of room at the bottom" for non-disciplinary Nanoobjects [37].

Therefore, *realconstructivistic technoobject-ID* turns out to be underlying the NBIC scenario. The types of ID is not a very strong one [38]. The technoobjects seem 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 microelectromechanical systems. Here, constructed and created interdisciplinary technobjects are essential parts of the present-day reality or the reality to come.

4. CONTRASTING WITH CTEKS …

Differences in knowledge politics are, however, obvious when we compare and contrast the NSF report with another prominent initiative. In 2004, an expert group of the European Commission (EC) developed "a specifically European approach to converging technologies" [39]. The EC group released a report entitled "Converging Technologies: Shaping the Future of European Societies", in detail: *C*onverging *T*echnologies for the *E*uropean *K*nowledge *S*ociety (CTEKS). The Europeans do not focus mainly on human enhancement but on broader aspects of societal innovation.

The EC group highly values ID, just as the NSF does. The European approach, however, advocates ID in a much broader understanding. The EC group considers plural perspectives and speaks about "Nano-Bio-Cogno-Socio-Anthro-Philo-Geo-Eco-Urbo-Orbo-Macro-Micro". Rather than striving for a convergence to/of techno-objects, technologies, or technosciences, the EC group aims to foster a converging "towards a common goal. CTs [= Converging Technologies] always involve 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." [40] The societal goals, purposes, and aims are at the core of the EC's understanding of ID, in particular the setting of the goals. Here, ID encompasses deliberate goal setting. Normativity is explicated by the CTEKS-approach. A explicit reflection on and revision of processes of "normative setting of goals"—as a basic element of "interdisciplinary excellence"—is intended [41]. To realize this, the European "CTEKS-research programs require and produce new standards for interdisciplinary research. ID usually means that researchers from various disciplines pool intellectual and technical resources as they address a problem together. This form of ID 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 ID." [42]

The EC stresses elements of participatory governance and technoscientific citizenship. Not only experts but also lay people should participate in this public process. "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 WiCC-initiative ('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." [43] Statements such as the foregoing are an excellent explication of problem-oriented ID. They represent a clear contrast to techno-object ID favored by the NSF report. The EC's idea to widen "the Circles of Convergence" means to reject the techno-object orientation, the metaphysical unity-of-nature metaphor of NSF's approach, and the cause-and-effect terminology. Broader aspects of the "Socio-Anthro-Philo-Geo-Eco [...]" are taken into account. Different kinds of convergence are worth thinking about, and, according to the EC group, they should be adjusted after the process of (normative) goal finding and agenda setting.

The EC group regards ethical considerations in public discourses as guidelines to shape the trajectories towards our common future(s). These trajectories should be intentionally set and selected in order to meet societal goals, cultural needs, and ethical standards. The EC group offers 16 recommendations; among them is the very central "ID" which is much more than simply an organizational principle. "ID should be strengthened, beyond planned or institutional collaboration, in program calls and research policies from the Commission and from the European nations." [44] Further: "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." [45] "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." [46] The EC group is not arguing in favor of the naturalization of social sciences and the humanities. They are very reluctant to speak about a unity of nature, integration, a unity of science and cause-and-effect-explanations.

SUMMARY AND OUTLOOK

We can distinguish four different types of ID in recent knowledge politics: the object type, the knowledge/theory type, the method/process type, and the problem/purpose type. By making use of analytical classification, I have shown that a specific type of ID is involved in the Roco-Bainbridge-report on converging technologies.

The comparison of the two contrasting visions of *Converging Technologies* might provide a further argument that the classification of the four different types of ID is a helpful analytic tool to investigate research programs and recent knowledge politics. Technoobject-ID and problem-oriented-ID are very different. This distinction might serve as a cornerstone for critically assessing the fluid buzzword "ID" in the various contexts of recent knowledge politics: Understanding interdisciplinarity turns out to be indispensable for the possibility of a normative assessment and adjustment of knowledge politics: Reflection on interdisciplinarity is the basis for a revision of knowledge politics. A critical revision of knowledge politics seems to be one of the major policy fields in our late-modern societies. Shaping interdisciplinary knowledge seems to be a central element for building late-modern societies. A *Reinvention of Politics* (Ulrich Beck) and a normative discourse on what is worth knowing—*as Knowledge Politics of Interdisciplinarity*—is indispensable in order to cope with pressing problems. Late-modern societies are faced with far reaching political questions: What kind of knowledge is necessary for the future of our societies? What knowledge should be promoted and developed?

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