Philosophy of Interdisciplinarity

Studies in Science, Society and Sustainability

Jan Cornelius Schmidt

First published 2022

ISBN: 978-1-138-23007-1 (hbk)
ISBN: 978-1-032-11846-8 (pbk)
ISBN: 978-1-315-38710-9 (ebk)

Chapter 2

Philosophy and plurality

Providing a classification and clarification of interdisciplinarity

DOI: 10.4324/9781315387109-2

The funder for this chapter is Darmstadt University

Routledge
Taylor & Francis Group
LONDON AND NEW YORK

2 Philosophy and plurality

Providing a classification and clarification of interdisciplinarity

Hot topic

Since the early 1970s and a path-breaking congress of the Organisation for Economic Co-operation and Development (OECD) in Paris, the need for a conceptual clarification of the term "interdisciplinarity," along with cognates such as "transdisciplinarity," has become obvious. Inter- and transdisciplinarity are in vogue in science, society, and economy. At the same time, both terms remain misty and unclear.

The vagueness might have posed a particular challenge to philosophers of science and analytic philosophers. Across all traditions and schools, they share the belief that a clear, distinct, and rigorous terminology is essential for knowledge generation and for communication.[1] Yet, although such a clarification might have become a canonical task, philosophers seem to feel uncomfortable addressing such a hot topic. This book intends to challenge their reluctance—and to support the scholarly and public debate on interdisciplinarity.[2] The aim in this second chapter is to provide a philosophical fundament—rooted in the tradition of philosophy—for a deeper clarification of the term. On that basis, we will later be able to develop a specific critical point of view.

Philosophy proves to be a rich resource for untangling the notion of interdisciplinarity. Referring to well-established distinctions in the philosophy of science, this chapter argues for a unity in plurality by examining four different types of interdisciplinarity in public and scientific discourses, namely interdisciplinarity with regard to objects (ontology); knowledge, concepts, and theories (epistemology); methods and heuristics (methodology); and pressing societal problems and issues. The philosophical framework of the four types or, we could say, the four framings of interdisciplinarity will be best illustrated by research programs that are prominently labelled "interdisciplinary." As will be discussed, it is striking that different philosophical traditions can be related to these four types. In fact, the different traditions determine which understanding of interdisciplinarity is favoured—and which types of interdisciplinarity are regarded as plausible and which not. Conversely, interdisciplinarity can serve as an excellent thematic focus for an introduction to philosophy of science—or, more precisely and

DOI: 10.4324/9781315387109-2

provocatively, to a "political philosophy of science" (Rouse 1987) or a "philosophy of science policy" (Frodeman and Mitcham 2004). The chapter reveals that a *minimal philosophy of science* constitutes an indispensable cornerstone of the *Philosophy of Interdisciplinarity*.[3]

Richness of the tradition

Philosophers seem to doubt whether the recent popularity of interdisciplinarity is justified. They are sceptical whether the label itself refers to a noticeably new mode of research. Seen in this light, interdisciplinarity appears to be merely a public, political, or ideological term that is part of a popular rhetoric and little more than a kind of parlance. This perception has fuelled scepticism about its value. Since philosophers claim to focus only on semantically relevant terms, interdisciplinarity is not regarded as a serious field of inquiry.

An additional reason for the reluctance of philosophers might be the mere fact that the phenomena associated with interdisciplinarity seem too complex, too heterogeneous, too dynamic, and too contextual to be accessible for philosophy, particularly for the philosophy of science. Interdisciplinary practice discourages a philosophical approach, as it appears to be non-universal, non-theoretical, context-specific, case-restricted, strongly value-laden, and often driven by non-epistemic values.[4] Expressed more provocatively, the limits of philosophy of science, notably in the analytic tradition, result in a reduced interest in interdisciplinarity among philosophers of science.

Despite the general reluctance, we find on closer examination that philosophy provides a rich framework for addressing interdisciplinarity. Although the word itself is not in philosophy's core vocabulary, the associated phenomena and topics are well known and hotly debated among philosophers. We find productive lines of thought in domains typically labelled monism, dualism, pluralism, inter-theoretic relations, holism, unification, and reduction. The ontological, epistemological, and methodological issues involved have occupied and challenged philosophic thinking since ancient times. In addition, new fields of philosophic engagement are paving the way towards a *Philosophy of Interdisciplinarity*. These include, for example, the history, sociology, and ethics of science; philosophy of technoscience; social epistemology; and political philosophy of science—all of which represent novel, vibrant, and exciting areas of philosophic inquiry. Some lines of thought to illustrate the richness of the tradition for our endeavour will be briefly outlined below.

But before doing so, let us explore what constitutes the field of inquiry of such a philosophic approach. A central goal of interdisciplinary practice is to bridge different disciplines, which leads to a certain level of integration and even to a synthesis or unification. Interdisciplinarity seems to be strongly needed in order to compensate for what has been lost over time: Although the functional differentiation and separation into disciplines have undeniably contributed to the impressive success of scientific explanation of the world and to the overall historical advancement of science—as seen, for instance, in quantum physics, cosmology, evolutionary theory, and synthetic or systems biology—there is a flipside. A patchwork of knowledge fragments, methods, and objects can be observed today. Diversity and even an overall disunity of sciences become apparent (Galison and Stump 1996). The academy appears to be fragmented or, worse, fractured into silos of disciplinary specialization: "knowing everything about nothing" (Ziman 1987).

Interdisciplinarity counteracts this development. It is regarded as a corrective or compensatory effort to regain a common way of looking at the world or even to achieve unity within the patchwork of disciplinary knowledge. The quest for such an integrative approach is by no means novel. Although the need for integration did not become apparent until the 20th century, in the period when differentiation, specialization, and fragmentation were at their strongest, integration has been an overall aim of academic inquiry since the ancient Greeks and, notably, since Plato. Leibniz, for instance, later renewed the goal of finding a common denominator and a synthesis of the world's fundamental knowledge with his ideal of a *mathesis universalis*. Traditional natural philosophy in the 18th and early 19th century sought unity in the diversity of the novel scientific insights on nature, the cosmos, and man. According to Hegel and others in the period of German Idealism, the truth has to be associated with the whole and not primarily with specialized, splintered, disciplinary insights.

Although the lines of arguments may have changed during the 20th century, the pursuit of integration of knowledge across disciplines remains as topical as ever. Most interestingly, and complementarily to the historical process of fragmentation, we can identify movements towards integration in many areas of the sciences themselves—forming a core element of synthesis or, stronger, of (inner-)disciplinary reduction. For instance, physicists have been and continue to be very successful at integrating and unifying different theories. They search for a "theory of everything" with the aim of bringing four fundamental forces or theories into a coherent body of a grand unified theory. Philosophers of science, standing in the tradition of the Vienna Circle and the Unity of Science movement of the 1920s and 1930s, have greatly valued the approach taken by physicists for being paradigmatic for the progress of science and scientific explanation. Strong forms of integration can be seen as a reduction[5]—meaning the dissolution of one theory into another such that the latter is then acknowledged as the more fundamental one. Accordingly, some advocates of interdisciplinarity turn out to be reductionists, too.

In contrast to the strong positions on integration and unification, which are not very common among interdisciplinarians, there are weaker and much more moderate positions to be found in the discourse surrounding interdisciplinarity. These focus on the "particulate unity of the empirical object," as Helmut Schelsky (1961) puts it.[6] The weaker positions presuppose a local, contextual, and provisional unity with regard to one object or domain instead of an overall unity throughout the entire world. They aim to address "the complexity, the totality, and the unity of one single object," as Ursula Hübenthal (1991) argues.[7] Often, these weaker positions on unity are developed from a pragmatic problem-oriented or real-world perspective with the goal of focusing on societally relevant objects or problems, which are so wicked, complex, and interrelated that a disciplinary approach is usually not feasible. Interdisciplinarity is regarded as a tool for tackling these complex issues. Methodological considerations for technology assessment, sustainability science, and social-ecological research have been developed along this line of thought (Decker 2001; Norton 2005). A certain local monism concerning objects and problems seems to be consistent with a global pluralism concerning methods, concepts, propositions, theories, and worldviews.

Whereas this weaker (second) position on unity often shows up in connection with integrating epistemic (intra-scientific) and non-epistemic (external, extra-scientific) values and is issue-driven (e.g., by global climate-change problems), the strong (first) position is an internal one. The internal–external distinction reflects the common parlance pertaining to interdisciplinarity and has given rise to the notion of "transdisciplinarity," which typically refers to the second position. This distinction, including the demarcation between science and society, touches on hot topics of present-day philosophy, such as the value dimension of science, the amalgamation of truth and power, questions concerning the legitimacy and authority of science in society at large, or the governance and shaping of science and research. Such topics are vigorously debated in new philosophical directions, namely in *social epistemology* (Fuller 2002).

In general, the two positions—the strong and the weak—share a positive view on the possibility of interdisciplinarity and its efficiency. Other positions, or thought traditions, are more pessimistic. A most prominent example of the latter might be Neo-Kantianism, including what has become known as the philosophy of culture. In the late 19th century, scholars such as Heinrich Rickert, Wilhelm Dilthey, and Wilhelm Windelband developed philosophical approaches underscoring the differences and unbridgeable gaps between natural science and the humanities—including the liberal arts, history, cultural studies ("Kulturwissenschaften"), and many fields of social science. These scholars favour demarcations and suggest several criteria to justify and defend the humanities, cultural studies, and social sciences as a distinct form of epistemic enterprise. In support of the battle against the growing dominance of the natural sciences in defining what epistemic knowledge and academic expertise are or ought to be, they also point to Immanuel Kant's thinking and his work on the "conflict of the faculties" from 1798. From today's perspective, Kant's work can be seen as a milestone in reflecting on the dissonance and unbridgeable gaps between the different disciplines.

A parallel stream of discourse deserves to be mentioned because it also shows the philosophic nature of the issues involved in interdisciplinarity. Since the late 1950s and a seminal essay by Charles Percy Snow, the term

"Two Cultures" has enjoyed an impressive growth in popularity (Snow 2001). Snow coined the term to characterize the very different mindsets, convictions, habits, socializations, and worldviews of natural scientists, on the one hand, and those of scholars from the humanities, liberal arts, and cultural studies, on the other. For interdisciplinarians, Snow's observation appears rather frustrating. Bridging the two-culture gap hardly seems possible at all.[8] Snow's thesis could also be derived from Thomas Kuhn's concept of paradigm or from Ludwik Fleck's idea of thought styles published about two decades earlier—although Kuhn and Fleck refer mainly to (intra-) disciplinarity (Kuhn 1970; Fleck 1979): If communication between communities that subscribe to different paradigms or thought styles is barely possible within one discipline, the same holds to an even greater extent for the communication between different disciplines. It can therefore be maintained that Kuhn and Fleck come to an even more pessimistic assessment than Snow. For the critical analysis undertaken here, it suffices to note that philosophy, particularly the philosophy of science, and the domain of social epistemology that became established from Kuhn onwards have much to offer when dealing with issues of interdisciplinarity.

Another confirmation of the pessimistic stance about interdisciplinary collaboration across the two-culture gap arose in the mid to late 1990s following an "experiment" conducted by the physicist Alan Sokal, who professed to being rather disappointed with the predominating intellectual quality and academic standards of postmodernist writing in the humanities, liberal arts, and cultural studies (Sokal 1996). To objectify his impression, Sokal launched an "experiment with the scholars of cultural studies." By setting up such a real-world experiment in which he made the editors and reviewers of a highly reputed journal of cultural studies his research object, he fuelled what became known as the "science wars" or "wars between the scientific cultures."[9] His experiment—or "hoax," as Sokal later called it—centred on a paper designed to appeal to postmodernists and authored by Sokal himself with the bombastic title "Transgressing the Boundaries: Towards a Hermeneutics of Quantum Gravity" (Sokal 1996). After successfully passing the review process, the manuscript was accepted by the very respectable humanities and cultural studies journal *Social Text*. After its publication, Sokal revealed that his paper was nothing but "fashionable nonsense" (Sokal and Bricmont 1998). The experiment, Sokal claimed, proved the decay of epistemic standards in the cultural studies and humanities. Sokal accused scholars in the humanities of neglecting to achieve truth, objectivity, and scientific quality. Sokal's own interpretation of his experiment did not only serve to fuel prejudices between the two cultures. On a much deeper level, it laid bare the friction between two philosophical viewpoints—realism and empiricism—which typically are associated with the natural sciences and engineering on one side of the debate and social constructivism and idealism, which are considered the canonical position of cultural scientists and scholars in the humanities, on the other side.[10] From the perspective of the *Philosophy of Interdisciplinarity*, one could conclude that the rigidness of the two thought traditions presents an obstacle to any interdisciplinary endeavour across both of them. The feasibility of interdisciplinarity cannot be taken for granted—as the notion's popularity might indicate. In sum, Sokal's experiment and the science war show how profoundly underlying philosophic positions are involved in the discourse and praxis of interdisciplinarity.

Let me next sketch another philosophical approach that envisions positive opportunities. Michel Serres (1992) seeks to renew philosophy as an academic discipline, albeit from a critical perspective. According to Serres, philosophy needs to address "interdisciplinary circulations" in the "web and knots of the sciences" and of "knowledge production."[11] In the process, a novel kind of philosophy, namely "philosophy of transport," could be conceptualized. Core elements of this interdisciplinarily oriented philosophy are "translations," "traductions," "transformations," "fluctuations," and "circulations" of knowledge, objects, and methods. For Serres, these unspecified and somewhat fluid keywords are central to characterizing "interdisciplinarity" as a form of knowledge production beyond disciplinary poles. A renewed philosophy will be engaged in the world:

> Philosophy does not just speak about the sciences, [...] it does not remain silent to the world that is based on sciences: Philosophy intervenes in the societal web of circulations. [...] Methods, models, propositions are circulating in the network; they are imported and exported, from everywhere to everywhere.[12]
>
> (Serres 1992, 8)

Every analysis of interdisciplinarity is an action, and any (act of) reflection simultaneously includes the potential revision of what is given. In line with Serres's thinking, a *Philosophy of Interdisciplinarity* can be regarded as a political endeavour since it encompasses a politics of translation, circulation, construction, differentiation, and integration of the "flows of knowledge." This broader orientation of philosophic inquiry goes beyond the 20th-century tradition of the philosophy of science.[13]

In light of the rich tradition of the philosophy of science—of which only some examples have been presented here—the reluctance of philosophers to address issues of interdisciplinarity seems incomprehensible. However, their failure to engage in the discourse on interdisciplinarity is perhaps due to the perception of the strong normative momentum of interdisciplinarity that is intertwined with non-epistemic values and, furthermore, with politics and society at large.

Motives and values

The tradition of philosophy presented above provides a first impression of the plurality of thinking in the field with which the *Philosophy of Interdisciplinarity* is concerned. Moving from the historical perspective to a more systematic approach, we are faced with another kind of plurality: the plurality of motives, values, or underlying goals. The tasks of the *Philosophy of Interdisciplinarity* are to identify and disentangle these and to render them open to critique.

Interdisciplinarians take the deficits of the disciplines and the isolation of disciplinary silos as their argumentative point of departure. Whenever "interdisciplinarity" is involved, so too are motives: Interdisciplinarians pursue—explicitly or implicitly—goals. They intend to change, renew, and restructure the sciences, the research system, and the academy or even society. Jantsch (1970), for one, as pointed out earlier, advocates a "self-renewal of the academy" and of the university structure, which he sees as the driving force for a necessary transformation of society at large. His revolutionary attitude concerning the betterment of society and the democratization of science, which was born in a time of student unrest, has met with strong opposition. Today, in line with the view held by the economist Jan Fagerberg (2005, 8), interdisciplinarity is frequently seen as—and reduced to—a resource of innovation involving the development of new technologies and long-term economic growth.[14] Such a view perfectly represents the dominant instrumental account of interdisciplinarity. Although these goals are very much present, they often remain hidden. The disregard of goals is part of the normalizing and mainstreaming process that has robbed interdisciplinarity of its critical momentum. Interdisciplinarians, nonetheless, cannot escape the normative.[15]

The notion of interdisciplinarity turns out to be a double-edged sword: On the one hand, interdisciplinarity can serve as a point of access and key catalyst for recognizing and reflecting on goals and motives of science and research in society. On the other hand, it can conceal goals and make such a debate impossible.[16] This ambivalence, or dialectic, needs to be considered and reflected upon by the *Philosophy of Interdisciplinarity*. Nevertheless, interdisciplinarity has the potential to spark deeper reflection on science and research in society. Putting this potential into practice is the guiding idea of the *Philosophy of Interdisciplinarity*.[17] A very first step in such a direction involves analysing the motives pursued by interdisciplinarians. In a nutshell, we can distinguish epistemic, economic, ethical-societal, and personal motives.[18] The respective values can be associated with truth (understanding, knowledge, insight, and objectivity—mostly curiosity-driven); utility (innovation, economic growth, and income); human and nature's well-being (basic needs, humanity, justice, democracy, peace, good life, benevolence, and sustainability); and sense-making (self-understanding, meaning, and world interpretation).

First, the *epistemic motive* frames science—and humanities—from the intra-academic perspective: Science is guided by the value of truth; it is curiosity-driven. The underlying diagnosis of the need for interdisciplinarity draws on the historically successful, functional differentiation within the academy that today reveals limits: Disciplinary boundaries turn out to hinder further advancement. Interdisciplinarity—loosely interpreted as boundary crossing and cross-fertilization—seems to be the only way to regain and ensure progress, restore knowledge production, and enable universal insight into the natural or social world. Traditionally, truth—according to Hegel's thinking—was associated with the whole and not primarily with the specialized, splintered knowledge of the disciplines. Interdisciplinarity is seen as a means to integrate and to synthesize the patchwork of disciplinary knowledge. The epistemic motive concerns interdisciplinary theories, methods, and objects in the overall architecture of the sciences.

Second, the *economic motive* does not focus primarily on the academy or on science from an intra-academic perspective: Utility is the base value by which scientific activity is framed and judged. Science is regarded as a means for obtaining and securing economic growth, prosperity, and wealth. Both Adam Smith and Karl Marx concurred, though from somewhat different angles, with Francis Bacon's viewpoint: Science is research that enables innovation and technological development; it secures international competitiveness. Accordingly, it appears to be the outstandingly powerful fundament and source of economic progress and wealth. When it comes to disciplinarity in the sciences and universities, serious deficits are manifest. The historically evolved, functional differentiation into academic disciplines does not lend itself to resolving real-world economic challenges; the utility of disciplinary knowledge is very limited. Economic practices and applications are regarded as being themselves in a certain sense inter- or transdisciplinary. In general, interdisciplinarity is seen as an instrument to overcome the disciplinary shortcomings. Considering this cluster of motives, Peter Weingart (2000, 39) speaks of "strategic" or "opportunistic interdisciplinarity."

Third, the *ethical-societal motive* is somewhat similar to the economic one, although it upholds different values. According to the ethical-societal viewpoint, research fulfils obligations within and for human and societal life. But in contrast to economic utility and technological innovativeness, the values associated with research activity are more comprehensive: They centre on the well-being of mankind, nature, and society and on sustainable development and intra- and intergenerational justice. The problems addressed in interdisciplinary research projects are therefore mainly socio-ecological, caused by the massive use of technology in society, as Erich Jantsch (1972) and Bryan Norton (2005) claim. Other scholars, such as Diana Hummel et al. (2017), additionally underscore the problematic driving forces of global capitalism. All share the view that disciplinary approaches are not adequate instruments to cope with real-world ethical-societal problems which are too complex, too wicked, and too hybrid. Interdisciplinarity is needed to tackle these problems; both normative and descriptive types of knowledge are required by political decision-makers and the public alike. These different types of knowledge have to be acquired and integrated in order to enable a sensitive, process-oriented approach to the management of complex systems.[19] Joint problem solving among science, technology, and society seems possible.

The *fourth motive* is driven by personal, metaphysical, or religious factors. The plurality of disciplinary patchworks and domain-restricted knowledge fragments creates incompatible cognitive worlds. Living in different, parallel worlds might, for some, have an almost schizophrenic impact. Interdisciplinarity is deemed a way to integrate pieces of disciplinary knowledge and connect them to a consistent or holistic picture of the entire world. The value associated with interdisciplinarity is one that is sense-making; in particular, it provides self-understanding. Such a view of interdisciplinarity shares some lines of thought with the metaphysical tradition of natural philosophy—and it also reflects some ideals of the Judeo-Christian tradition.

The foregoing list of motives is not exhaustive, but it reveals the principal grounds for interdisciplinary engagement. Moreover, it can contribute to an explicit discourse on the values associated with interdisciplinarity: The epistemic motive is guided by the value of truth; non-epistemic motives are dominated by economic values such as utility or by ethical-societal values such as human and nature's well-being, sustainability, justice, and the like; sense-making is central to personal values. In addition, the fact that multiple motives exist indicates a first plurality in our effort to clarify interdisciplinarity.

Boundaries

A philosophical approach to interdisciplinarity, as proposed in this book, naturally offers a more profound analysis than a straightforward classification of motives and values. Reflecting only on motives could easily lead to a mere descriptive approach entailing a limited view of interdisciplinarity. The *Philosophy of Interdisciplinarity* aims to critique, complement, and widen the view. One of its central objectives is to reveal underlying philosophical assumptions and fundamental convictions regarding the notion of "interdisciplinarity" —and on this basis it advances a critical perspective that opens up avenues towards sustainable knowledge within the academy (cp. Frodeman 2014).

To start with, interdisciplinarity is based, in one way or another, on disciplinarity; the term itself appears, initially, to be a derivative of disciplinarity.[20] Although the latter is not much simpler to define than the former, shifting the focus onto disciplinarity can prompt a fresh way of thinking about the field of interdisciplinarity: Interdisciplinarity urges us to rethink disciplinarity, particularly with regard to the institutional constitution of the academy, to the authority and power of disciplinary gatekeepers, and to the criteria for what counts as scientific knowledge.

In fact, the philosophy of science has shown that disciplines cannot be adequately grasped as coherent structures rooted in given domains, distinguished methods, or certain theoretical entities. Although these aspects may certainly play a role, disciplines should be perceived as historically conditioned institutional structures that are, to a greater or lesser extent, constituted by the social sphere—which is itself influenced by societal trends, historical contexts, economic interests, political decisions, and power and authority games.[21] Bearing that in mind, we can consider the two assumptions that constitute the core components of interdisciplinarity. *First*, whenever one speaks of interdisciplinarity, a *boundary premise* is present. Boundaries—which are central to any kind of differentiation, demarcation, separation, segregation, or fragmentation—are perceived to exist between disciplines as well as between academia and society. Not only do boundaries contribute to delineating disciplines, they also represent barriers and obstacles to knowledge production; boundaries are synonyms for limits and limitations.[22] *Second*, the *transcendence or transgression premise* assumes that options to overcome those boundaries are available. Interdisciplinarity aims to facilitate the transfer, circulation, synthesis, integration, or unification of disciplinary perspectives; it is typically linked to the ideal of bridging disciplines and integrating the splintered fragments of disciplinary knowledge.[23]

Taking these two complementary premises of "interdisciplinarity" results in what could be called a *boundary paradox*: the conservation *and* elimination of boundaries at the same time. The elimination of disciplinary boundaries would naturally render conservation impossible—and interdisciplinarity would dissolve. In fact, the elimination of interdisciplinarity pursuant to the elimination of boundaries has been and still is a frequently occurring phenomenon in the academic system. The historical institutionalization of computer science and informatics during the 1960s and early 1970s provides a prominent example of the gravitational pull of the normalization or mainstreaming process by which interdisciplinarity is eliminated by the creation of a new discipline. A newly institutionalized "interdiscipline" rapidly turns into a new discipline with a new regional ontology. This disciplinary pull is always a threat to interdisciplinary efforts.

Descriptively, the elimination of interdisciplinarity through the formation of a new discipline might be of interest to research fields such as the science studies or the history of sciences. From a philosophical perspective, however, we must underscore that boundaries are indispensable, and also constitutive, for any research activity labelled "interdisciplinary." Instead of "boundary paradox," a more appropriate term to describe the tension between conservation *and* elimination might be "boundary dialectic." Locating the notion of interdisciplinarity within dialectic thinking—which comes close to Hegel's *Aufhebung*—highlights that interdisciplinarity always holds a hidden critical potential. Interdisciplinarity is both dependent on disciplinarity *and* a challenge to disciplinarity. A critical-reflexive approach, as set forth throughout this book, is intrinsically bound to the recognition of and reflection on boundaries. Hence, any concept of interdisciplinarity requires a reference to boundaries and, more specifically, it requires a boundary-based dialectic concept of (a) separation and differentiation and of (b) transcendence and integration.

Employing dialectic thinking enables us to reject prominent interpretations that associate interdisciplinarity solely with integration, synthesis, fusion, unification, or holistic thinking.[24] Those positions—that also advocate overarching methods, integrative techniques, and step-by-step procedures—appear one-sided or even self-contradictory. That can be said, for instance, of the suggestion of establishing a "discipline of interdisciplinarity" and "disciplining interdisciplinarity" (Bammer 2013).

Interestingly, boundaries are an old and ongoing philosophical topic, which touches on fundamental questions about the structure of the world, the possibility of scientific knowledge, and ways to acquire that knowledge. Well-known philosophic positions embrace monistic or dualistic concepts (ontologies and epistemologies) interlaced with topics such as (non-)reductionism. Over the last thirty years, philosophers and social scientists have inquired extensively into boundaries[25] but with only very occasional reference to interdisciplinarity. Interdisciplinarians themselves, on the other hand, rarely consider boundaries and borders explicitly, although these notions are broadly taken for granted. The large overlap of the two fields carries huge potential for cross-fertilization and mutual learning. The discourse on interdisciplinarity could, for instance, undoubtedly derive benefit from the line of thought of Ulrich Beck and Christoph Lau (2004), who seek to establish a "boundary politics in the age of boundary dissolution and border elimination."[26]

To sum up, the key point is that reflection on boundaries—that is, the recognition, setting, and maintaining as well as the transcendence and transgression of boundaries; in short: *boundary work* (Gieryn 1983)—can be considered central to reflection on interdisciplinarity. Since any adequate definition of "interdisciplinarity" refers semantically to boundaries, the *Philosophy of Interdisciplinarity* needs to explicitly address boundaries and provide a conceptual framework encompassing both (a) separation or differentiation and (b) transgression, transcendence, or integration. Hence, any concept or theory of interdisciplinarity has to fulfil this twofold dialectic requirement, namely to provide a concept of separation *and* of integration.

Distinguishing different types

As set forth above, boundaries are essential. They represent central elements of the *Philosophy of Interdisciplinarity* and specifically are constitutive for advancing a critical-reflexive account of interdisciplinarity.[27] In the following, I develop a framework of different dimensions or non-disjunctive types of interdisciplinarity[28] which refers to boundaries and fulfils the two related requirements.

While the (*intensional*) semantic core of "interdisciplinarity" consists, on a general level, of boundaries, the different types will show that interdisciplinarity is a multifaceted phenomenon. That is to say, from a philosophic viewpoint, the *extension* or scope of the term has to be characterized by a plurality: a plurality of types united in a semantic core of boundaries. Such a framework—being central to the *Philosophy of Interdisciplinarity*—is not an end in itself but will be used in order to analyse, assess, and critique interdisciplinary research programs. By employing distinctions that are well established in the tradition of philosophy—such as those between objects (ontology), knowledge/theory (epistemology), methods (methodology), plus one central additional aspect, namely problems—we can identify four types or dimensions of interdisciplinarity, and we can relate this result to what has become known as transdisciplinarity.[29]

First, an object-oriented or ontological type of interdisciplinarity can be defined in terms of objects, entities, or structures of reality such as the human brain, the evolution of the earth, the ozone hole, nanoparticles, nuclear power plants, personal computers, the internet, skyscrapers, water supply systems, or military infrastructures. The basic assumption with regard to this kind of interdisciplinarity is that the historical, functional differentiation of the academy into institutionalized disciplines does not seem absolutely contingent. Rather, the differentiation mirrors aspects of the nature of the things themselves. Interdisciplinary objects are deemed to be located within or built into the deep structure of reality. Edmund Husserl, Nicolai Hartmann, Alfred North Whitehead, and others argue, for instance, in support of a structurally layered concept of reality according to which interdisciplinary objects would lie on the boundaries between different micro-, meso-, macro-, and other cosms or within the border zones between disciplines. Some examples include brain-mind objects, nano-objects, or entities of synthetic biology. To advocate this position, one must presuppose an ontological realism or at least a real-constructivism[30] concerning objects, interlaced with a layered concept of reality, and, based on this, an ontological non-reductionism.[31] Old and ongoing issues about ontological monism, dualism, and pluralism emerge in this debate. Interdisciplinarity according to this view is not concerned mainly with knowledge, methods, or research goals but above all with a reality that is assumed to be independent of humans. A minimal realist view of the things is involved. More recent versions of this position do not assume the timeless, somewhat Platonic existence of objects.[32] New interdisciplinary objects are constructed and created through the massive spread of technologies or are cognitively constructed by the sciences themselves. Examples include the hole in the ozone layer, high-frequency trading on the stock exchange, or virtual objects in computer science. The massive spread of human-constructed objects, sometimes labelled "human-created nature," also supports the observation that we are witnessing an epochal break with regard to ontology, as Martin Carrier (2011, 51) argues.

Second, a knowledge and theory-oriented type of interdisciplinarity sees epistemological aspects as the central criterion. The focus lies on knowledge, propositions, theories, models, and concepts[33] and not primarily on objects or methods. The crucial questions in this case are the following: How can we demarcate interdisciplinary knowledge from disciplinary knowledge or from non-scientific knowledge? How should we specify interdisciplinary theories, models, laws, descriptions, and explanations? Do these provide a specific conceptual understanding of the objects under consideration? Potential candidates for interdisciplinary theories or concepts include meta-theories, which can be applied to describe very different disciplinary objects. According to this understanding, an interdisciplinary theory highlights structural similarities between the properties of different objects from various disciplines. Systems theory is one of the most prominent examples of an interdisciplinary theory, as is cybernetics and, to a certain extent, some variants of the theory of evolution. Furthermore, strong arguments have been put forward over the last fifty years claiming that, on a deeper level, we are witnessing the emergence of novel interdisciplinary theories, specifically self-organization theories, which provide an evolutionary, dynamic, self-organizing understanding of the entire world. As elaborated above, the basic requirement is that an interdisciplinary theory must not be reducible to a disciplinary one; that is, interdisciplinary theories do not fit into disciplinary frameworks. An epistemological non-reductionism of interdisciplinarity with regard to disciplinary theories is the most compelling stance. Theory-oriented interdisciplinarity questions the ideal of the covering-law model and the feasibility of grand unification based on the subsumption of all phenomena under a disciplinary law. Given the historical development of the sciences and, in particular, of such concepts as systems theory, it is overall evident that theory-oriented interdisciplinarity does not constitute an epochal break or a rupture in the theoretical core of the sciences.

Third, interdisciplinarity is often viewed from a methodological angle and frequently regarded as a challenge to scientific methodology.[34] A method-oriented type of interdisciplinarity can be identified. Methodology generally refers to knowledge production, the research process, rule-based actions of scientists, procedures of inquiry, and the languages used therein. In methodology, the main issue is how, and by which rules and procedures, can we obtain knowledge and insight. This procedural understanding of the sciences—science as research—is sometimes called context of discovery or the research form of science to distinguish it from the context of justification, which refers to knowledge, theories, or propositions.[35] Rough, classical categorizations distinguish between empirical and hermeneutic, nomothetic, and ideographic methods as well as (more generally) between the methods of the natural sciences and those of the humanities or between explanation and understanding. With respect to interdisciplinarity, some of the central questions are the following: Do interdisciplinary methods and actions exist? Is there a specific context of discovery prevalent in interdisciplinary projects? Which validity, evidence, and quality criteria can be applied to the results of interdisciplinary projects? Do they differ from those in disciplinary projects? Interdisciplinary methods are thought to be irreducible to disciplinary ones. Outstanding prospects are ascribed to those interdisciplinary methods that facilitate the transfer of knowledge between disciplines and also to those that combine descriptive, normative, and abductive methods of reasoning beyond disciplinary havens. In addition, other scholars see interdisciplinarity as a (transdisciplinary) method to bridge the gap between the academy and society—in other words, methods are interdisciplinary when they enable, facilitate, and foster knowledge production between the academy and society in one way or another.

Fourth, we need to add another level of reflection—since it is quite common to speak of interdisciplinarity in connection with addressing certain problems that are deemed beyond the scope of a specific discipline and even outside the academy. This type of interdisciplinarity is often described as problem-oriented, purpose-driven, or issue-focused or—with a slightly different meaning—as transdisciplinarity (see also Figure 2.1); it is important to point out that transdisciplinarity should not be restricted to cases where stakeholders or lay people are involved in the process of knowledge production.

Compared with the three other types of interdisciplinarity, the fourth approach frames science and research from a more comprehensive perspective. It centres on problems and issues, and it includes the goals, purposes, initial conditions, and research agendas of scientific activities. This approach concurs, for instance, with the thinking of Jürgen Habermas (1971), who adverts to the guiding interests of scientists and their research agendas. It is typically based on the assumption of a teleological structure governing the process of knowledge production: A trajectory is presupposed to exist from the point of agenda setting—where the problems are perceived or defined—to the anticipated results.

The problem dimension, or the "context of problems," notably the will to know, precedes both the "context of discovery" and the "context of justification" (i.e., the methods and theories). Despite the obvious significance of the points of departure—in the field of interdisciplinary research and also in disciplinary research—philosophers have surprisingly rarely acknowledged such a broader and more appropriate view of the sciences. Their reluctance might stem from a fear that problems, because of their being obviously value-laden, cannot be separated from the social dimensions of research activity. Outside the mainstream of philosophy of science, thought-provoking approaches have been pursued under the label of the new field of social epistemology (Fuller 2002)—although scholars in this field have not inquired in-depth into problems and agenda-setting procedures. The same holds for innovative fields of the social sciences in which scholars have addressed so-called "wicked problems" (Rittel and Webber 1973). The structure of problems, however, has hardly been clarified and understood: Problems therefore remain a "no man's land" in terms of explicit reflection (see Chapter 5).

In regard to interdisciplinary problems, it could at first sight (a) be generally assumed that they may be merely epistemic in nature; they can emerge through intra-academic progress and require an interdisciplinary effort within the sciences (see Figure 2.1). For instance, problems in the field of physical cosmology demand collaboration among physics, chemistry, geology, and computer science. Solving these problems is of interest to the sciences and serves their truth seeking but does not have wide-ranging relevance for society at large. In addition, (b) interdisciplinary problems can emerge within the economic or business field. Finding solutions to these trans-scientific or extra-scientific problems is guided by the value of

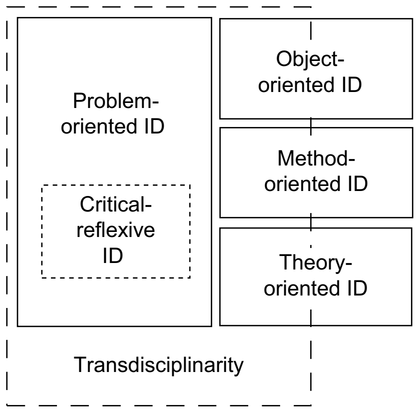

Figure 2.1 Landscape of the definitions employed in this book. We can distinguish four types or dimensions of interdisciplinarity (ID): object-oriented ID, method-oriented ID, theory-oriented ID, and problem-oriented ID. The last focuses on societally or ethically relevant (extra-scientific) problems and can be regarded as instrumentalist. Some problem-oriented interdisciplinary projects are also critically reflexive: The latter category is a subset of problem-oriented ID. In addition to a mere means-centred instrumentalist approach, critical-reflexive (problem-oriented) ID also involves reflection on and, if deemed necessary, the revision of the problems, goals, purposes, or values of research agendas. Of most interest is the overall relation of ID to transdisciplinarity (TD) insofar as TD is a very popular notion. The latter should not be restricted to or defined by referring just to the involvement of (extra-scientific) lay people or stakeholders (see this Chapter 2). Since TD addresses trans-epistemic, extra-scientific, or real-world issues (= mode 2, trans-science, post-normal science, technoscience, and the like), TD and ID (in particular: TD and problem-oriented ID) need to be distinguished. Some disciplinary issues are transdisciplinary but *not* interdisciplinary and, more specifically, *not* problem-oriented interdisciplinary (e.g., the design and construction of a bridge). In fact, many engineering challenges are to be considered disciplinary *and* transdisciplinary. Conversely, certain interdisciplinary objects (object-oriented ID) cannot be considered transdisciplinary, such as the cosmos (in particular, the cosmic evolution of the universe) or the human brain and its (self-)consciousness. Since problem-oriented ID always refers to real-world or trans-scientific, societally/ethically relevant problems, problem-oriented ID is effectively a subset of transdisciplinarity. In addition, some interdisciplinary objects cannot be classified as problem-oriented, such as (techno-)objects on the nano-scale that extend across the borders between physics, chemistry, biology, informatics, material engineering, and others. Nano-scale projects are very technically centred and therefore cannot be regarded as being problem-oriented, although they are clearly transdisciplinary since they are associated with extra-scientific or trans-epistemic goals. Therefore, the notion of problem-oriented transdisciplinarity is one that makes sense. The point to recall is that projects may be disciplinary *and* transdisciplinary (e.g., bridge construction) or interdisciplinary *and* non-transdisciplinary (e.g., the cosmic evolution). Transdisciplinarity is not the counterpart to (and not a disjunctive form of) disciplinarity.

economic utility and is often motivated by the growth imperative of shareholder value.

However, although both kinds of interdisciplinary problems clearly pose challenges to interdisciplinary collaboration, they are usually *not* what interdisciplinarians have in mind when they speak of "problem-oriented," "issue-initiated," or "purpose-driven" interdisciplinarity. Let us therefore discuss the concept of problem-oriented interdisciplinarity and distinguish the notion of problem used in this context from the two kinds of interdisciplinary problems outlined above. Of most interest is the overall relation of interdisciplinarity to transdisciplinarity in general.

Problem-oriented interdisciplinarity is always transdisciplinary (ad a): Although the advocates of problem-oriented interdisciplinarity do not deny the existence and scientific relevance of *intra-epistemic* problems,[36] they stress the transdisciplinary nature of the type of problems they focus on and refer to interdisciplinarity as transdisciplinarity.[37] In general, the notion of transdisciplinarity underscores a trans-academic or extra-epistemic orientation of knowledge production: Science produces knowledge *within* and *for* society or the economy.

Now, when interdisciplinarians describe their approach as transdisciplinary, they are not denying that traditional disciplines such as certain engineering or technical sciences can be seen as being transdisciplinary-oriented.[38] The key point made by interdisciplinarians in labelling their work "transdisciplinary" is that the nature of the problems addressed in their projects is overall trans-academic: These problems—sometimes referred to as "real-world problems"—are not deemed relevant only by the peers of a certain scientific discipline (e.g., engineering scientists) or by scholars of the academy but by society at large.

Furthermore, *problem-oriented interdisciplinarity is more specific than transdisciplinarity; the former is a subset of transdisciplinarity* (ad b). With regard to the second kind of problems discussed above—those in the economic or business realm—it is to be noted that, while economic problems can obviously have a transdisciplinary dimension and often require interdisciplinary research, the notion of problem-oriented interdisciplinarity is generally linked to societal and ethical motives. These problems are primarily ones that represent challenges to society at large, such as the climate change, the loss of biodiversity, the limits of energy resources, the new regional wars, the threat posed by atomic weapons, the nuclear waste of power plants, the threat to human health by environmental pollution, and the global injustice surrounding the worldwide distribution of wealth. For instance, all issues that hinder us from pursuing the goals of sustainable development represent the kind of problems addressed by problem-oriented interdisciplinarity. The notion of transdisciplinarity is therefore much broader in scope and more unspecific than problem-oriented interdisciplinarity.[39] Furthermore, transdisciplinarity should not be reduced to stakeholder and lay people involvement, as Jaeger and Scheringer (2018) convincingly argue.

To provide a deeper and more detailed explication, I will now further distinguish between two kinds or modes of problem-oriented interdisciplinarity. One mode involves reflection on and, if deemed necessary, the revision of the problems and goals of research agendas—which includes an argumentative justification of the relevance of the problems addressed. Contrary to this first mode, the second one accepts problems as being simply given. Throughout this book, the former will be termed the *critical-reflexive kind* of problem-oriented interdisciplinarity whereas the latter is primarily an *instrumentalist* or *strategic account*. The relation between the two modes will be elaborated on; it will be shown that the critical-reflexive approach can be seen as a subset of the instrumentalist account of the fourth type of interdisciplinarity, namely of problem-oriented interdisciplinarity. The other three types of interdisciplinarity discussed above—the object-, theory-, and method-oriented type—share an instrumental dimension with the instrumental mode of problem-oriented interdisciplinarity.

Taking stock of the arguments presented so far, "interdisciplinarity" is semantically justifiable if, and only if, at least one of the four types or dimensions can be ascribed to it. At the same time, the four types are not exclusive or disjunctive. It is possible that a specific research project fulfils more than one dimension: For example, it may be both problem- *and* object-oriented. In a later subsection of this chapter, we will see how different philosophic convictions determine how the different types of interdisciplinarity are seen to be related.

Examples

The framework of the four types of interdisciplinarity can be further illustrated by some popular examples of research programs that are considered "interdisciplinary." These examples also give further substance to the classification advanced by the *Philosophy of Interdisciplinarity*.

First, let us consider interdisciplinary objects and the ontological type of interdisciplinarity. Nanoresearch is one of the most prominent fields that claim to be interdisciplinary—for instance, in an influential report presented by the US National Science Foundation (Roco and Bainbridge 2002).[40] In 1959, the physicist Richard Feynman stressed the presence of "white and unconquered domains" on the "disciplinary map of sciences": There seems to be "plenty of room at the bottom" (Feynman 2003).[41] According to Feynman, nano-objects are located between the microscale of quantum physics and the mesoscale of chemistry and biology. Some of them are designed, constructed, and created by researchers; others existed or came into existence independently before the emergence of nanoresearch but have now been discovered or brought under control. Nano-objects are interdisciplinary in nature insofar as they lie on (or between) the boundaries of scientific disciplines, whereas the boundaries themselves are thought to mirror the deep ontological structure of reality.[42] Interdisciplinary nano-objects seem to be the unifying core and umbrella notion encompassing the heterogeneous fields of nanoresearch and nanotechnology, which include electron-beam and ion-beam fabrication, molecular-beam epitaxy, nano-imprint lithography, projection electron microscopy, atom-by-atom manipulation, quantum-effect electronics, semiconductor technology, spintronics, and micro-electromechanical systems.[43] In these examples, interdisciplinary objects are an essential part of reality on an ontological level: The nano-objects, constructed in a joint effort by the disciplinary fields of physics, chemistry, biology, and engineering sciences, are today regarded as technoscientific objects. Nano-objects—and object-oriented interdisciplinary research—have not yet been perceived by philosophers and social scientists, with the exception of Martin Carrier (2011), as a type of interdisciplinary engagement.

Similarly, the objects with which neuroscience is concerned are located on various boundaries between the disciplines (i.e., between the natural sciences, social sciences, and the humanities). Interdisciplinary neuroscientific objects are much more complex than nanotechnological objects. Furthermore, socio-technical objects, such as the water supply system, the internet, or the hole in the ozone layer, are further examples of interdisciplinary objects that are representative of object-oriented interdisciplinarity.

Second, let us now turn our attention to epistemological interdisciplinarity, which relates to knowledge, theories, models, and concepts. Systems theory and complex systems are examples of interdisciplinary theories and interdisciplinary knowledge. Cognitive integration and a theoretical synthesis of knowledge—which avoids the trap of reductionism—are goals that have been partly attained in this area. Other interdisciplinary concepts, which are very similar to and interlaced with complex systems theory, include self-organization theories, dissipative structures, synergetics, chaos theory, nonlinear dynamics, fractal geometry, and catastrophe theory (Mainzer 1996; Schmidt 2008a, 2011a, 2019). Most of these concepts were established in the late 1960s and early 1970s, although some foundational work dates back to the late 19th century. Hermann Haken (1980), for instance, regards his research field of synergetics as an "interdisciplinary theory of general interactions." Erich Jantsch (1980) views self-organization theories and the general concept of evolution as a "unifying approach" with multiple "implications to the sciences and the humanities." Edward O. Wilson (1998) anticipates a new "consilience" entailing a "unity of knowledge," for instance, through research programs in socio-biology. Klaus Mainzer (2005, v) identifies within complex systems theory "the basic principles of a common systems science in the 21st century, overcoming traditional boundaries between natural, cognitive, and social sciences, mathematics, humanities and philosophy." On closer scrutiny, however, this type of theory-oriented interdisciplinarity, which could also be characterized as meta-disciplinary or non-disciplinary,[44] is not as novel as it might appear. It is also found in works from the 1950s. At that time, the physicist and philosopher Carl Friedrich von Weizsäcker (1974, 23) coined the term "structural sciences."[45] As Weizsäcker writes, structural sciences "study their objects regardless of disciplinary origin and in abstraction from disciplinary allocation." Weizsäcker had in mind concepts such as information theory or cybernetics.

Today, structural sciences have been extended and enriched by complex systems theory, which investigates nonlinear, unstable, and chaotic behaviour in dynamic systems and describes processes as they evolve over time, such as pattern formation, self-organization, critical behaviour, bifurcations, phase transitions, structure breaking, and catastrophes. Complex systems theory addresses old questions concerning the emergence of new phenomena and about novel properties, patterns, entities, and qualities. One important lesson provided by this interdisciplinary concept for all sciences is the fundamental role of instabilities in nature, technology, and even in social processes.[46]

Third, we will go deeper into the methodological type of interdisciplinarity. Bionics or biomimicry could be regarded as prominent examples of an interdisciplinary method.[47] These fields claim to provide a method of transfer between two disciplines: from biology to engineering sciences and probably (though this is usually not acknowledged) vice versa. The central idea of bionics is, it is maintained, to "learn from nature" in order to "inspire technological innovations" and to "optimize artifacts and technical processes" (Benyus 2002). Nature is seen as being productive. As such, it serves as a source of inspiration for inventions that can be used for the design and construction of new technical systems. The proponents of bionics are convinced that nature "reaches its goals efficiently and economically, with a minimum of available energy and resources. The experience available in nature can be applied to conduct technological research and development" (Hill 1998). Interdisciplinarity in the methodological sense is here based on a kind of "translation" or "transfer" between nature and technology—more specifically between certain framings, representations, perceptions, understandings, or models of nature and of technology. "Learning from nature" therefore means learning from *models* of nature: Nature is not simply given but is constituted or constructed, as Immanuel Kant argued. The models of nature built in the field of bionics are based on the perspective of engineering sciences. For example, a robot may be a technical model of an ant and therefore mimic the ant, but at the same time the ant is modelled by the bionics researcher from a technological perspective. Construction and reconstruction—in this case technology/engineering science, on the one hand, and biology, on the other—are, at least to some degree, merged since the goal of bionics is not only to produce knowledge but also to create technological artefacts. Bionics can be seen as a paradigm of a *technoscience* based on an interdisciplinary method of transfer across the *border or trading zone* between biology and engineering (Galison 1996; Gorman 2010).

There are further examples of interdisciplinary methodologies besides bionics. Econophysics, which methodologically organizes a knowledge transfer between physics and finance/economics, is another paradigm of the methodological type of interdisciplinarity that is very similar to bionics.[48]

Further examples encompass transdisciplinary methods employed in problem-oriented interdisciplinary projects aimed at organizing and managing the knowledge transfer and production between the extra-scientific and academic participants (Pohl and Hirsch Hadorn 2007; Bergmann et al. 2012).

Fourth, the most far-reaching type of interdisciplinarity is problem-oriented interdisciplinarity, often referred to as transdisciplinarity—although not all transdisciplinary projects are to be considered problem-oriented or even interdisciplinary (see Figure 2.1). As outlined earlier, interdisciplinary problems can in general be inner-academic ones emerging in the curiosity-driven domain of truth seeking within the sciences, such as problems regarding the origin of life on earth or dealing with the characteristics of consciousness of the human brain. However, these are not the kind of problems that scholars specifically mean when they use the expression "problem orientation." So we need to look beyond the curiosity-driven academic field and beyond an economic perspective on interdisciplinarity. Technology assessment, sustainability science, and social ecology are paradigms of problem-oriented interdisciplinary approaches. Research in these fields starts from the perception of pressing interdisciplinary problems that are seen as being societally and ethically relevant.[49] These fields aim to obtain systems, target, and transformation knowledge (Pohl and Hirsch Hadorn 2007)—accompanied by consideration of the possible societal impact of new and emerging technologies (e.g., side effects, risks, and potentials)—in order to address prospective problems as early as possible.

Problem-oriented interdisciplinarity as a specific type of interdisciplinarity has its own history. We may recall that Jantsch, at an OECD conference in the early 1970s, called for "inter- and transdisciplinarity" not only in an academic context but also for societal and ethical purposes. Jantsch accused the university and academic systems of being incapable of addressing the pressing real-world problems such as warfare (involving atomic, chemical, or biological weapons); environmental problems such as global warming and the loss of biodiversity; waste production, disposal, and contamination; shrinking natural resources; problems with water and food quality; and anthropological problems in connection with the ambivalence of biomedical progress.

This book is dedicated mostly to problem-oriented inter- or transdisciplinarity; further examples—in particular, ones seeking to obtain a different view of nature and the environment—will be discussed later on.

Schools of thought

The four types of interdisciplinarity sketched above can be regarded as *ideal* types, which, granted, do not occur exclusively in particular scientific practices or programs, and they are by no means disjunctive in the sense that a research practice or program can be subsumed under one type or another. For example, a specific research program claiming to be interdisciplinary can be both problem- and method-oriented. Nonetheless, one type of interdisciplinarity will typically dominate whereas the other types are seen as derivatives that are related in one way or another to the principal type. Moreover, which of the types of interdisciplinarity will take precedence over which is undeniably open to discussion and subject to justification. A method-oriented interdisciplinary research program, for instance, can be seen as a consequence of a certain problem orientation or vice versa.

In light of the foregoing considerations, the *Philosophy of Interdisciplinarity* endeavours to provide additional arguments to confirm the existence and prevalence of the four types of interdisciplinarity. Most interestingly, one's philosophical background conviction is what, consciously or unconsciously, predetermines which of the four types one might consider most relevant and which types one might see as inferences, derivations, or mere consequences.[50] The *Philosophy of Interdisciplinarity* enquires into the philosophical background and into the various implicit philosophies influencing the discourse on interdisciplinarity.

With their primary focus on objects, things, and artefacts, realists and (to some extent) empiricists, new experimentalists, and real-constructivists first assume the existence of given or constructed objects which can be cognitively perceived from an objective angle. In this object-centred account, interdisciplinary research—like any research activity—commences directly on the ontological level. The need for interdisciplinarity stems from the essential structure of the objects located beyond or across disciplinary boundaries. Given the very existence of interdisciplinary objects, one has to select or develop adequate (namely interdisciplinary) methods; the methods are assumed to be prescribed by the structure of the objects. Furthermore, interdisciplinary knowledge—for realists, empiricists, and others—originates in or results from the interdisciplinary objects themselves. In sum, a realist or empiricist position is central to being able to defend object-oriented interdisciplinarity. Those who deny the plausibility, soundness, or justification of the object-oriented view of interdisciplinarity are at the same time attacking some of the central assumptions of realism, empiricism, or new experimentalism.

Rationalists, *second*, tend to frame interdisciplinarity by referring primarily to knowledge, theories, models, concepts, theoretical entities, or even mathematical structures. According to such a rationalist perspective, interdisciplinarity becomes necessary because of the increasing fragmentation of knowledge and the lack of unity: Interdisciplinarity is regarded as an attempt to counteract this development. Its goal is to contribute to a broader view of the things by bridging, synthesizing, integrating, or unifying various knowledge fragments from different disciplines and subdisciplines. The guiding ideal is to provide a coherent picture of the whole of reality or at least of those things that are regarded as a central part of reality. In contrast to the belief underpinning object-oriented interdisciplinarity, the different academic disciplines are *not* assumed to mirror different natures of the objects, but are defined by a specific kind or corpus of knowledge, theories, or models. The theory-oriented type of interdisciplinarity certainly seems the most ambitious given that it requires a process of cognitive integration or even unification. According to this understanding of interdisciplinarity, theories or concepts have first priority and precede the selection of methods, the framing of objects, and the definition/constitution of problems. Object-, method-, and problem-oriented interdisciplinarity are therefore seen as derivatives of theory-oriented interdisciplinarity.

Many interdisciplinarians—notably methodological constructivists,[51] scholars from science and technology studies, and some pragmatists—*third*, tend to reflect on methods, rules of knowledge production, practical procedures, or heuristics. They regard science as a method-based action (i.e., as a research activity). Accordingly, interdisciplinarity is defined by methods: Interdisciplinary methods are considered to be non-reducible to disciplinary ones. Interdisciplinarity from this perspective challenges researchers to set up new procedural rules, to create a vocabulary overlapping disciplines, to establish novel validity or evidence criteria, and, in addition, to organize the collaboration among the disciplines, and to institutionalize interdisciplinary research processes. The recent predominance of disciplinary cultures—and, more specifically, of disciplinary orientations, validity criteria, heuristics, habits, vocabularies, and languages—poses major obstacles to interdisciplinarity. The primacy of methods means that interdisciplinary problems, objects, and knowledge are mere derivations or consequences of the respective methods.

A different approach to interdisciplinarity, *fourth*, is taken by pragmatists, utilitarians, critical theorists, and others such as political philosophers and many ethicists insofar as they refer to problems, goals, purposes, and interests. According to them, the need for interdisciplinarity is due to the emergence of pressing problems that do not fit into the disciplinary differentiation of the academy. Holders of these viewpoints evaluate interdisciplinarity by its ability to pragmatically define or address problems. Typically, the problems in question have societal and ethical relevance. The advocates of problem-oriented interdisciplinarity see the framing, construction, or reconstruction of objects as a mere consequence of the perception or constitution of problems. The methods, and also the ensuing knowledge, are regarded as derivations.

To summarize, philosophical schools of thought serve as lenses through which one views both the disciplinary and the interdisciplinary scenery. They determine what meaning and significance one is willing to attach to interdisciplinarity—and which order of priority, hierarchy, or chain of inference of the different types of interdisciplinarity one is willing to subscribe to. Given the relevance and prevalence of the four positions on interdisciplinarity, an elimination of the plurality of understandings and their reduction to a single meaning—beyond the twofold, dialectic reference to boundaries—is not feasible. The plurality of notions of interdisciplinarity mirrors the plurality of the different intellectual traditions and schools of thought in philosophy. Therefore, the debate on interdisciplinarity is, in a broader sense, philosophical in nature.

Conclusion and prospects

The typology of interdisciplinarity presented in this chapter is intended to serve as an orientation framework. With reference to established positions in philosophy, different types of interdisciplinarity can be distinguished: the object-oriented type, the theory-oriented type, the method-oriented type, and the problem-oriented type, the last of which can be regarded as an effective subset of what is known as transdisciplinarity. On a more general note, transdisciplinarity opens science to society; it is not an oxymoron to see transdisciplinary disciplines. More specifically, the problem-oriented type of interdisciplinarity, as a subset of transdisciplinarity, considers ethical and societal aspects. Thus, we can also speak of problem-oriented transdisciplinarity.

Above all, the semantic core of interdisciplinarity is tightly connected to boundaries. This entails a dialectic relation between boundary setting and preserving *and* at the same time transcending and overcoming boundaries. The acknowledgement of an underlying dialectic relation gives substance to a twofold requirement that is intertwined with both non-reductionism *and* integration (or synthesis): Interdisciplinary objects, theories, methods, and problems are deemed to be irreducible to disciplinary ones. Ontological, epistemological, and methodological boundaries, as well as the boundaries of the academic system, are seen as obstacles or barriers to various kinds of reductionism. On the other hand, boundary-crossing is an indispensable aspect of interdisciplinarity. In fact, the bridging of boundaries or the transfer of knowledge across boundaries can be viewed as a kind of integration, synthesis, or reduction.

Therefore, interdisciplinarity is inherently linked with a philosophical position that can be called *integrative non-reductionism* or *non-reductive integrationism*. It shares much with a newly proposed concept, namely *integrative pluralism* (Mitchell 2009).[52]

Notes

1 According to this viewpoint, not the objects appear to be messy and vague, but rather the terms or propositions in which we represent them.
2 See, among others, Balsinger (1999, 2005), Hubig (2001), Grunwald and Schmidt (2005), Schmidt (2008b), Frodeman (2010), Krohn (2010), Jungert et al. (2010), Wechsler and Hurst (2011), and Gethmann et al. (2015).
3 However, philosophy of science should not be viewed in the limited sense in the tradition of analytic philosophy, but from a broader perspective including social epistemology, political philosophy of science, ethics of science, philosophy of technoscience, history of science, and more.
4 See the analysis by Krohn (2010), Gethmann et al. (2015), and Krohn et al. (2017).
5 For a critique, see Holbrook's (2013) line of argument.
6 My translation (J.C.S.).
7 My translation (J.C.S.).
8 Snow's thesis was later supported by an empirical study conducted by the philosopher Schurz (1995).
9 An introduction to the "science wars" is given from various perspectives in Bammé (2004) and Segerstrale (2000).

10 The "science wars" later abated when Hacking (1999) advocated a pluralist understanding of constructivism and of realism. Hacking showed that Sokal's pessimistic conclusion is based on rough assumptions and prejudices, for example, on some elements of a naive scientific realism.
11 My translation from the German version (J.C.S.).
12 My translation from the German version (J.C.S.).
13 This is in line with Frodeman's (2010, 2014) agenda to renew (Anglo-American analytical) philosophy.
14 For a critique, see Maasen (2010).
15 This is an experience similar to that facing scientists during a revolutionary phase in which the paradigm, the disciplinary matrix, and the underlying norms dissolve.
16 See, for instance, Weingart and Stehr (2000).
17 As such, the *Philosophy of Interdisciplinarity* can be seen as a central element of a critical-reflexive interdisciplinary practice. That is to say, the critical-reflexive type of interdisciplinarity includes the *Philosophy of Interdisciplinarity*.
18 A cognate distinction that refers to "values" is presented in Gethmann et al. (2015) and Machamer and Wolters (2004). For a more specific account of values regarding sustainable development goals (SDGs), see Norton (2015).
19 See the argumentation offered in Norton (2005).
20 See also Balsinger (1999, 2005), Turner (2000), and Jungert et al. (2010). From an analytic perspective, this point is inescapable, although Krohn (2010, 33) advances a thought-provoking understanding of interdisciplinarity without referring to disciplines.
21 New fields of philosophical inquiry such as social epistemology, science and technology studies, and technoscience studies paint a very colourful and diverse picture of the various disciplines and subdisciplines.
22 In this vein, Frodeman (2014, 3) sees "the notion of limit" as "a core meaning" of inter- or transdisciplinarity.
23 An extreme kind of integration is known as reduction.
24 Arguments against the integrationist stance are provided by Holbrook (2013).
25 An explicit reflection on boundaries can be found in Star and Griesemer (1989) and Löwy (1992)—and, from a different angle, in Beck and Lau (2004).
26 My translation (J.C.S.).
27 Since acknowledging and reflecting on boundaries are not only a prerequisite for, but also an indispensable part of, any good interdisciplinary practice, the *Philosophy of Interdisciplinarity* can be seen as a central and essential component of interdisciplinary practice.
28 A thought-provoking approach towards a continuum of types of interdisciplinarity has been developed by Szostak (2015) and Szostak et al. (2017).
29 A draft of this typology is developed in Schmidt (2005) and Schmidt (2008b).
30 The position of real-constructivism (see Schmidt 2011b) is not fully developed in philosophy, although the "new experientalism" has argued in favour of it (e.g., Hacking 1983, 1999).
31 Ontological reductionism holds that the world consists of atoms or other fundamental material entities ("materialism") or, on the contrary, of mental entities ("idealism").
32 As the sciences progress and scientific institutions change over time, objects that were previously interdisciplinary can be shifted into domains of new disciplines with their novel regional ontologies.
33 Hübenthal (1991) identifies "concept interdisciplinarity" as a specific type of interdisciplinarity which is concerned with systems theory, cybernetics, synergetics, information theory, and others. For a general consideration of complexity and systems theory, see Kline (1995).

34 See, for example, Pohl and Hirsch Hadorn (2007), Hirsch Hadorn et al. (2008), or Bergmann et al. (2012).
35 This highly disputed distinction can be traced back to the Vienna Circle and Hans Reichenbach.
36 A distinction between *intra*-scientific and *extra*-scientific (transdisciplinary) problems is usually presupposed. It can be traced back to heated debates in the philosophy of science on the subject of internalism and externalism (cf. Böhme et al. 1983). Transdisciplinary problems are considered to be science-*external*. A split is assumed between science and society. For a discussion of this issue from a sociological perspective, see Cozzens and Gieryn (1990).
37 This view is in line with the thinking of Gibbons et al. (1994).
38 It would be absurd, indeed, to conceive of engineering research on renewable power plants, electric cars, fuel cells, railway bridges, lighter materials, or atomic weapons as a mere epistemic or inner-academic enterprise.
39 As outlined, "problem-oriented transdisciplinarity" is a subset of "transdisciplinarity." Therefore, we can also talk about "problem-oriented transdisciplinarity." The two terms—"problem-oriented interdisciplinarity" and "problem-oriented transdisciplinarity"—are synonyms.
40 For a more detailed analysis, see Chapter 3.
41 Nanoresearch is based on technological advancements: scanning tunnelling microscopy and the atomic force microscope, which stem from developments in the early 1980s.
42 Indeed, there may be an ontological boundary or a boundary zone between the microscale and the mesoscale in which the given or constructed objects can be located.
43 See also Chapter 3. Since many problems in nanoresearch are driven by extra- or trans-scientific/-epistemic motives or needs—that are typical for engineering sciences—most areas of nanoresearch are also to be characterized as transdisciplinary.
44 Other authors also refer to the framework of systems theory when considering a conceptual foundation of interdisciplinarity (Kline 1995).
45 Original German term: *Strukturwissenschaften*; see, for example, Küppers (2000, 89ff.).
46 See also Chapter 7 in this book.
47 For an introduction to this field, see Benyus (2002), Nachtigall (1994), Maier and Zoglauer (1994), and Schmidt (2002). Klein (2000, 3f.) speaks of "borrowing" with regard to methods.
48 For an introduction to this field, see Mantegna and Stanley (2000) and McCauley (2004).
49 See, for instance, Gethmann (1999), Decker (2001, 2004), Chubin et al. (1986), and Lingner (2015).
50 Even interdisciplinarians who never explicitly engage with philosophical thought traditions have their implicit philosophies on which their perceptions, actions, and judgments of interdisciplinarity are based.
51 This is a philosophic position developed in German-speaking countries (Lorenzen 1974; Janich 1984; Janich 1992) that has not been broadly recognized by the international community of philosophers of science.
52 Admittedly, integrative non-reductionism would require further elaboration—which, alas, goes beyond the scope of this book (aspects are discussed in Schmidt 2015a).