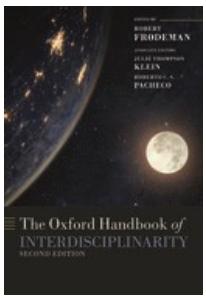

The Oxford Handbook of Interdisciplinarity (2nd edn)

Robert Frodeman (ed.)

https://doi.org/10.1093/oxfordhb/9780198733522.001.0001

Published: 2017 **Online ISBN:** 9780191838903 **Print ISBN:** 9780198733522

CHAPTER

3 Typologies of Interdisciplinarity: The Boundary Work of Definition

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https://doi.org/10.1093/oxfordhb/9780198733522.013.3 Pages 21–34

Published: 06 March 2017

Abstract

The dominant structure of knowledge in the twentieth century was division into domains of disciplinary specialization. In the latter half of the century this system was challenged by an increasing number of interdisciplinary activities. This chapter examines typologies of interdisciplinary activities, identifying patterns of consensus and fault lines of debate from the first major classification scheme in 1970 and continues to recent taxonomies that recognize new developments. The chapter compares similarities and differences in a framework of multidisciplinary juxtaposition and alignment of disciplines, interdisciplinary integration and collaboration, and transdisciplinary synthesis and trans-sector problem solving. It further distinguishes major variants of methodological versus theoretical interdisciplinarity, bridge building versus restructuring, and instrumental versus critical interdisciplinarity. Typologies are neither neutral nor static. They reflect choices of representation in a semantic web of differing purposes, contexts, organizational structures, and epistemological frameworks. They reassert, extend, interrogate, and reformulate existing classifications to address both ongoing and unmet needs.

Keywords: multidisciplinary, interdisciplinary, transdisciplinarity, integration, collaboration, methodology, theory, bridge building, restructuring, instrumentality, critique

Subject: Epistemology, Philosophy

Series: Oxford Handbooks

TYPOLOGIES classify phenomena based on similarities and differences, whether sorting artistic genres, medical symptoms, animal and plant species, or forms of knowledge. Over the course of the twentieth century, knowledge in the Western intellectual tradition was classified into specialized domains within a larger system of disciplinarity. In the latter half of the century, though, that system was supplemented and challenged by an increasing number of interdisciplinary activities. The most prominent way of organizing them has been to construct typologies that group related activities into categories labeled by technical terms.

The first major set of terminology appeared in 1970, created for an international conference co-sponsored by the Organization for Economic Cooperation and Development (OECD). It classified interactions of disciplines into categories of multi-, pluri-, inter-, and trans-discipinarity (Apostel 1972). Other labels soon followed, resulting in a profusion of jargon some have likened to a tower of Babel. Harvey Graff (2015), for one, faults the "name game" for generating more confusion than clarity, charging, "The endless typologies, classifications, and hierarchies of multi-, inter-, and transdisciplinarities are not helpful." Graff himself, though, adopts a hierarchical distinction between multi- and inter-disciplinarity throughout his comparative study of interdisciplines in order to reinforce integration as a primary criterion. More significant for this chapter, dismissing terminology fails to recognize its value for tracking definitions over time. Terms are sometimes used interchangeably, but patterns of consensus reveal continuities and discontinuities in theory and practice.

Typologies are neither neutral nor static. They reflect political choices of representation by virtue of what is included or excluded, which activities are grouped within a particular category, and how narrow or wide the field of vision is in a spectrum ranging from small academic projects to society at large. Taken together these choices constitute a form of boundary work in a semantic web that indexes differing purposes, contexts, degrees of integration and interaction, organizational structures, and epistemological frameworks. Thomas Gieryn (1983) coined the term "boundary work" in a study of demarcating science from non-science. He defined boundary work as an ideological style that constructs boundaries rhetorically
p. 22 in three major ways: expanding authority or expertise into other domains, ↳ monopolizing authority and resources, and protecting autonomy over professional activities. Interdisciplinary terminology performs all of these functions. It asserts alternative forms of research and education, often pegged against disciplinary specialization as the foundation of knowledge. It prioritizes some forms over others, in subcategories of interdisciplinarity and the heightened imperative of transdisciplinarity. And, networks and organizations use labels to stake claims for particular kinds of work. The three most widely used terms in the OECD typology constitute a core vocabulary amplified by technical distinctions for particular contexts.

The chapter distinguishes the first two generic terms—*multidisciplinarity* (MD) and *interdisciplinarity* (ID)—followed by major variants of methodological and theoretical ID, bridge building and restructuring, instrumental and critical ID. It then examines the current momentum for transdisciplinarity (TD) and closes by reflecting on implications of new typologies. Table 3.1 depicts key terms and their characteristics, degrees of integration, and contrasting types that appear throughout the chapter.

Table 3.1 Table of Definitions

Key Terms and Characteristics		
Multidisciplinarity	Interdisciplinarity	Transdisciplinarity
Juxtaposing	Interacting	Transcending
Sequencing	Integrating	Transgressing
Coordinating	Focusing	Transforming
	Blending	
	Linking	
Degrees of Interdisciplinary (ID) Integration		
Lack of Integration	Integration	
Encyclopedic ID	Generalizing ID	
Indiscriminate ID	Integrated ID	
Pseudo ID	Conceptual ID	
Contextualizing ID	Structural ID	
Composite ID	Unifying ID	
Contrasting Types		
Auxiliary Disciplinary Relations	Supplementary Disciplinary Relations	
Bridge Building	Restructuring	
Borrowing	Hybridization	
Shared ID	Cooperative/Collaborative ID	
Narrow ID	Broad or Wide ID	
Methodological ID	Theoretical ID	
Instrumental ID	Critical ID	
Strategic or Opportunistic ID		

Endogenous ID	Exogenous ID
	Trans-sector Transdisciplinarity
	Coproduction of Knowledge

3.1 Multidisciplinary Juxtaposition and Alignment

Most definitions of ID, Lisa Lattuca found in a literature review, treat integration of disciplines as the "litmus test." In fields that prioritize critique of knowledge, this premise is disputed. Nevertheless, integration is the most common benchmark (2001, pp. 78, 109). The OECD typology classified MD as "[j]uxtaposition of various disciplines" (Apostel 1972, p. 25). Juxtaposition fosters wider scope of knowledge, information, and methods. Yet, disciplines remain separate, retain their original identity, and are not questioned. This tendency is widespread in conferences and publications that present serial views of a shared topic or problem. Likewise, many purportedly "interdisciplinary" curricula and research projects combine separate disciplinary approaches without proactively integrating them around a designed theme, question, or problem. The keywords in Rebecca Crawford Burns' typology of integrative education capture the limited relationship of disciplines and subjects. When placed in parallel order they are in a *sequencing* mode and when intentionally aligned a *coordinating* mode (1999, pp. 8–9). In both cases, however, integration is lacking.

3.1.1 Encyclopedic, Indiscriminate, and Pseudo Forms

This part of the spectrum of definition is often deemed superficial, reinforcing a boundary between MD and ID. As the keywords "sequencing" and "coordinating" suggest, MD is encyclopedic in nature. In a six-part typology, Margaret Boden deemed *encyclopedic ID* a "false" or "weak" form, citing loose communication in joint degrees and co-located information on the World Wide Web (1999, pp. 14–15). Similarly, Heinz Heckhausen categorized encyclopedic forms as *indiscriminate ID*, citing the *studium generale* of German education and exposure to multiple disciplines in professional education. Mindful of false claims, Heckhausen added the concept of *pseudo ID*, embodied in the proposition that sharing analytical tools such as mathematical models of computer simulation constitutes "intrinsic interdisciplinarity" (in Apostel 1972, pp. 87). Certain disciplines are also deemed "inherently interdisciplinary" because of their synoptic scope, including philosophy, literary studies, and religious studies as well as anthropology and geography. Synoptic identity signifies breadth more than integration of multiple parts. Despite falling short of ID, however, MD plays a valuable role in expanding the knowledge base for a given project or program and has even been deemed a characteristic of contemporary disciplines because of their plurality of practices.

3.1.2 Contextualizing, Informed, and Composite Relationships

The practice of applying knowledge from one discipline to contextualize another further illustrates the limits and value of MD. A philosopher might use history to inform readers about a particular movement in philosophy or, vice versa, use philosophy to provide epistemological context for a particular event. Boden's classification *contextualizing ID* is evident in another familiar practice, organizing discipline-based chapters
p. 24 serially in books on ↳ the same theme or topic. Proximity widens scope, but here too integration around shared themes or questions is lacking (Boden 1999, pp. 15–16). Heckhausen's term *composite ID* labels another familiar practice—applying complementary skills to address complex problems or to achieve a shared goal. He cited societal problems such as war, hunger, delinquency, and pollution, while calling peace research and city planning "interdisciplinarities in the making" because they simulate exploring interdependencies (in Apostel 1972, p. 88). Even with a common framework, though, knowledge production retains a strong disciplinary thrust. In biosciences, for example, technical knowledge from many fields and expensive instruments are often shared. Despite crossing boundaries, however, disciplinary relations do not necessarily change or individuals collaborate.

3.2 Interdisciplinary Integration and Collaboration

The OECD definition of ID was wide, encompassing any interaction ranging from "simple communication of ideas to the mutual integration of organizing *concepts, methodology, procedures, epistemology, terminology, data,* and organization of research and education" (in Apostel 1972, p. 25). Simple communication, though, does not entail key traits that Burns and Lattuca argue constitute ID. Integrated designs prioritize focusing, blending, and linking. In education for instance, courses achieve a more holistic understanding of a cross-cutting question or problem by combining historical and legal perspectives on public education or biological and psychological aspects of human communication (Burns 1999, pp. 11–12; Lattuca 2001, pp. 81–83). Scope varies though, ranging from narrow to wide or broad ID depending on the number of disciplines involved and the compatability of their epistemological paradigms and methodologies.

Many believe that ID is synonymous with collaboration. It is not. However, heightened interest in teamwork to solve complex intellectual and social problems has amplified the connection while fostering greater attention to the interaction of cognitive and social integration. Degrees of cooperation differ, though. In Boden's concept of *shared ID* groups tackle aspects of a complex problem. Yet, collaboration does not necessarily occur. In contrast, *cooperative ID* requires teamwork, exemplified by the collaboration of physicists, chemists, engineers, and mathematicians in the Manhattan Project to build an atomic bomb and in research on public policy challenges such as energy and law and order (1999, pp. 17–19). Differences are further evident in methodological versus theoretical ID.

3.2.1 Methodological Interdisciplinarity

The motivation in methodological ID is to improve the quality of results, typically by borrowing a method or concept from another discipline to test a hypothesis, to answer a research question, or to help develop a theory (Bruun et al. 2005, p. 84). Degrees of influence vary, though. If a borrowing does not result in a significant change in practice, Heckhausen explained, disciplines are in an *auxiliary* relationship. If it
p. 25 becomes more sophisticated and ↳ enduring dependence develops, the relationship is *supplementary*, exemplified by incorporation of psychological testing into pedagogy and neurophysiological measures in psychology (in Apostel 1972, pp. 87–89). In a six-part typology, Raymond Miller identified two forms of interdisciplinary work that are methodological in nature. The first, shared components, includes methods shared across disciplines, such as statistical inference. The second, crosscutting organizing principles, are focal concepts or fundamental social processes used to organize ideas and findings across disciplines, such as "role" and "exchange" (1982, pp. 15–19). New engineering and technological methods were also developed during World War II, stimulating postwar borrowings of cybernetics, systems theory, information theory, game theory, and new conceptual tools of communication and decision theories. And, the roster of shared methods includes techniques such as surveying, interviewing, sampling, polling, case studies, cross-cultural analysis, and ethnography.

Borrowing across social sciences and humanities also illustrates methodological ID. In 1980, Clifford Geertz identified a broad shift within intellectual life in general and social sciences in particular. The model of physical sciences and a laws-and-instances explanation was being supplanted by a case-and-interpretation model and symbolic form analogies borrowed from humanities (see Krohn, this volume). Social scientists were increasingly representing society as a game, a drama, a text, or a performance, rather than a machine or a quasi-organism. They were borrowing methods of speech-act analysis, discourse models, and cognitive aesthetics, crossing the traditional division of explanation and interpretation. And, social sciences were not immune from the influences of existentialism and phenomenology, structuralism, deconstruction, poststructuralism, neo-Marxism, and comparative cultural studies. On the other side of the disciplinary fence, humanists were taking anthropological, sociological, political, and historical turns in scholarship while borrowing concepts of "motives," "authority," "persuasion," "exchange," and "hierarchy." Conventional rubrics remain, Geertz concluded, but they are often jerry-built to accommodate a situation that is "fluid, plural, uncentered, and ineradicably untidy."

3.2.2 Theoretical Interdisciplinarity

Theoretical ID connotes a more comprehensive general view and epistemological form embodied in creating conceptual frameworks for analyzing particular problems, integrating propositions across disciplines, and synthesizing continuities between models and analogies. The Academy of Finland Interdisciplinary Research (AFIR) team cited a project to develop a model of mechanisms that mediate mental stress experiences into physiological reactions and eventually coronary heart disease. Previous studies emphasized correlation of single stress factors or separate personal traits associated with the disease. In contrast, the project aimed to develop an interdisciplinary theory based on integration of psychological and medical elements and testing the conceptual tool of inherited "temperament" (Bruun et al. 2005, p. 86).

Theoretical forms of ID are often ranked as more "genuine" than methodological forms. For Boden, the highest levels are *generalising ID* and *integrated ID*. In generalizing ID, a single theoretical perspective applies to a wide range of disciplines, such as cybernetics or complexity theory. In integrated ID, which Boden deems "the only true interdisciplinarity," concepts and insights of one discipline contribute to
p. 26 problems and theories of another, ↳ a process evident in computational neuroscience and the philosophy of cognitive science. Individuals may also find their disciplinary methods and theoretical concepts modified as a result of cooperation, fostering new conceptual categories and methodological unification (1999, pp.

19–22). Comparably, Lattuca considers *conceptual ID* the "[t]rue or full" form of ID. Core issues and questions lack a compelling disciplinary basis, and critique of disciplinary understanding is often implied (2001, p. 117). Parallels also arise in the difference between bridge building and restructuring.

3.3 Bridge Building versus Restructuring

In 1975 the London-based Nuffield Foundation's Group for Research and Innovation identified two basic metaphors of ID—bridge building and restructuring. Bridge building occurs between complete and firm disciplines, while restructuring detaches parts of several disciplines to form a new coherent whole. A third possibility occurs when a new overarching concept or theory subsumes theories and concepts of several disciplines, akin to the notion of TD (Group for Research and Innovation, 1975, pp. 42–45). Landau, Proshansky, and Ittelson's typology of two phases in the history of interdisciplinary approaches in social sciences illustrates the difference between bridge building and restructuring. The first phase, dating from the close of World War I to 1930s, was embodied in the Social Science Research Council and University of Chicago school of social science. The interactionist framework at Chicago fostered integration, and members of the Chicago school were active in efforts to construct a unified philosophy of natural and social sciences. The impacts were widely felt, and occasionally disciplinary "spillage" led to formation of hybrid disciplines, such as social psychology and political sociology. However, traditional categories of knowledge and academic structures remained intact.

The second phase, dating from the close of World War II, was embodied in "integrated" social science courses, a growing tendency for interdisciplinary programs to become "integrated" departments, and the concept of behavioral science. Traditional categories anchoring disciplines were questioned and boundaries blurred, paving the way toward a new theoretical coherence and alternative divisions of labor. The behavioral science movement, in particular, sought an alternative method of organizing social inquiry rather than tacking imported methods and concepts onto traditional categories. In addition, the concept of "area" posited greater analytical power while stimulating a degree of theoretical convergence also potential in the concepts of role, status, exchange, information, communication, and decision-making (Landau et al. 1962, pp. 8, 12–17).

3.3.1 Interdisciplinary Fields, Interdisciplines, and Hybrid Specializations

The formation of new interdisciplinary fields is a major case of restructuring. Miller identified four categories in a typology of interdisciplinary approaches. *Topics* are associated with problem areas. "Crime,"
p. 27 for instance, is a social concern appearing in multiple social ↳ science disciplines as well as criminal justice and criminology. "Area," "labor," "urban," "environment," and "the aged" also led to new academic fields. *Life experience* became prominent in the late 1960s and 1970s with the emergence of ethnic studies and women's studies. *Hybrids* are "interstitial cross-disciplines" such as social psychology, economic anthropology, political sociology, biogeography, culture and personality, and economic history. And, *professional preparation* led to new fields with a vocational focus, such as social work and nursing.

Some new fields are considered a hybrid type of ID. When new laws become the basis for an original discipline, Marcel Boisot contended, a more formal *structural* relationship emerges, such as electromagnetics and cybernetics (in Apostel 1972, pp. 94–95). Heckhausen also deemed the point at which biology reached the subject matter level of physics and biophysics an example of *unifying ID* (in Apostel 1972, pp. 88–89). Proposing hybridization as a general process of development, based on studies of innovation in social sciences, Dogan and Pahre identified two stages. The first is specialization, and the second continuous reintegration of fragments of specialties. They also identified two types of hybrids. The first type becomes institutionalized as a subfield of a discipline or a permanent cross-disciplinary program.

The second type, exemplified by the topic of "development," remains informal. Hybrids, moreover, beget other hybrids, especially in natural sciences where higher degrees of fragmentation and hybridization are present (1990, pp. 63, 66, 72).

The emergence of new communities of practice and networks often leads to proclamations of a new discipline, perpetuating an oversimplified belief that the interdiscipline of today is the discipline of tomorrow. This generalization, however, ignores wide variances in both interdisciplines and disciplines (Graff 2015). Some areas, such as systems science, have gained disciplinary status, anchored by shared principles, unifying core concepts, and a new community of knowers with a common interlanguage. Others though, such as nanoscale research, are widely dispersed and bounded within individual domains. Economic and social capital are also powerful determinants in the political economy of ID. The growth of area studies, for instance, was facilitated by significant amounts of funding from the Ford Foundation. Molecular biology also enjoyed a level of support lacking in social psychology, and the same discrepancy appears today in the differing status of biomedicine and digital humanities.

More than one label might apply in the same field as well, depending on which points of interaction and degrees of integration are being described. Richard Lambert (1991) called the field of area studies, for example, a "highly variegated, fragmented phenomenon, not a relatively homogeneous intellectual tradition." Much of what could be called "genuinely interdisciplinary" work, he judged, occurred at the juncture of four disciplines providing the initial bulk of area specialists: history, literature and language, anthropology, and political science. At that hybrid space, a historically informed political anthropology developed using material in local languages. Blending of disciplinary perspectives occurred most often at professional meetings and in research by individual specialists. In scholarly papers the dominant pattern was broadly defined themes, creating a collective "multidisciplinary" perspective with the topic of any one event driving the disciplinary mix. At the same time, area studies research is "subdisciplinary" when concentrated in particular subdomains, even as the field at large is deemed "transdisciplinary" in scope.

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3.4 Instrumental versus Critical Interdisciplinarity

The difference between instrumental and critical ID is another fault line in the discourse of ID. In an analysis of forms of interdisciplinary explanation, Mark Kann identified three political positions. Conservative elites want to solve social and economic problems, without concern for epistemological questions. Liberal academics demand accommodation but maintain a base in the existing structure. And, radical dissidents challenge the existing structure of knowledge, demanding ID respond to the needs of oppressed and marginalized groups (1979, pp. 187–188). Methodological ID is "instrumental" in serving the needs of a discipline or field. During the 1980s, however, another kind of instrumental ID akin to Kann's first political position gained priority in science-based areas of economic competition such as computers, biotechnology and biomedicine, manufacturing, and high-technology industries. Peter Weingart labeled related activities *strategic* or *opportunistic ID* that serves the needs of the marketplace and the nation (2000, p. 39).

In contrast, critical ID interrogates the dominant structure of knowledge and education with the aim of transforming it, raising questions of value and purpose silent in instrumental ID. New fields in Miller's "life experience" category were often imbued with a critical imperative, older fields such as American studies took a "critical turn" in the 1960s and 1970s, and a "new interdisciplinarity" emerged in humanities and cultural studies signified by "anti," "post," "non," and "de-disciplinary" labels. Indicative of this trend, Lattuca found an increasing number of faculty in humanities and social sciences do interdisciplinary work with the explicit intent of deconstructing disciplinary knowledge and boundaries, blurring boundaries of the epistemological and the political (2001, pp. 15–16, 100).

Critical ID also refigures the relationship of disciplinarity and ID. Giles Gunn (1992) depicted differing constructions of the relationship in a typology of interdisciplinary approaches in literary studies. The simplest approach to mapping is tracking relations with other disciplines, for instance literature *and* philosophy or anthropology. Each coupling exposes cross-secting influences, such as hermeneutics in the relationship with philosophy or ethnography with anthropology. The conjunctive strategy, though, remains on disciplinary ground. The map changes if asking a different question. What new subjects and topics have emerged? Other examples appear, such as history of the book, psychoanalysis of the reader, the sociology of conventions, and ideologies of gender, race, and class. Studies of textuality also evolved into studies of representation. "The threading of disciplinary principles and procedures," Gunn found, "is frequently doubled, tripled, and quadrupled in ways that are not only mixed but, from a conventional disciplinary perspective, somewhat off center." They are characterized by overlapping, underlayered, interlaced, crosshatched affiliations, collations, and alliances that have ill-understood and unpredictable feedbacks. The final development is the most difficult to map. Correlate fields such as philosophy and anthropology have themselves changed, challenging assumptions about the strength of boundaries while working to erode them. Gunn concluded, "The inevitable result of much interdisciplinary study, if not its ostensible purpose is to dispute and disorder conventional understandings of relations between such things as origin and terminus, center and periphery, focus and margin, inside and outside."

p. 29 The distinction between instrumental and critical forms, it should be said, is not absolute. Research on problems of the environment and health often combine critique and problem solving. Nonetheless, a clear division appears in typologies. Observing trends in the medical curriculum, Bryan Turner (1990) argued that pragmatic questions of reliability, efficiency, and commercialism take center stage when ID is conceived as a short-term solution to economic and technological problems. In contrast, in social medicine and sociology of health ID emerged as an epistemological goal focused on the complex causality of illness and disease. Researchers focused on psychological, social, and ethical factors in an alternative holistic biosocial or biopsychosocial model that is critical of the limits of the traditional hierarchical biomedical model.

(See Frodeman [2013] and Jacobs [this volume] for two contrasting views of the relationship of disciplines and ID, the first asserting dissolution of disciplines while prioritizing problem-focused TD and the second reasserting the primacy of disciplines.)

3.5 Transdisciplinarity

The recent ascendancy of TD is a prominent development in the history of ID. In the OECD typology, TD was defined as a common system of axioms that transcends the scope of disciplinary worldviews through an overarching synthesis, such as anthropology conceived as the science of humans. Three participants in the OECD seminar differed, though, in elaborating the concept. Jean Piaget treated TD as a higher stage in the epistemology of interdisciplinary relationships based on reciprocal assimilations. Andre Lichnerowicz promoted "the mathematic" as a universal interlanguage, and Erich Jantsch embued TD with social purpose in a hierarchical model of the system of science, education, and innovation (in Apostel 1972). Since then, the term has proliferated. Four major trendlines appear at present.

The first trendline is a contemporary version of the epistemological quest for systematic integration of knowledge. The quest for unity spans ancient Greek philosophy, the medieval Christian *summa*, the Enlightenment principle of universal reason, Hegelian philosophy, Transcendentalism, the search for unification theories in physics, and E. O. Wilson's theory of consilience. Reviewing the history of TD, Joseph Kockelmans (1979) found it has tended to center on educational and philosophical dimensions of sciences. The search for unity today, though, does not follow from a pregiven order. It must be continually "brought about," Kockelmans emphasized, through critical, philosophical, and supra-scientific reflection. It also

accepts plurality and diversity, an underlying value of the Centre International de Recherches et Études Transdisciplinaire (CIRET). The center is a virtual meeting space for a new universality of thought and type of education informed by the worldview of complexity in science.

The second trendline is an extension of the OECD definition of synthetic paradigms. Miller defined TD as "articulated conceptual frameworks" that transcend the narrow scope of disciplinary worldviews. Leading examples include general systems, structuralism, poststructuralism, Marxism, phenomenology, feminist theory, and sustainability. Holistic in intent, these frameworks propose to reorganize the structure of knowledge by metaphorically encompassing parts of material fields that disciplines handle separately
p. 30 (1982, 21; see also Stribos, this volume). In the early twenty-first century a variant of this trendline ↳ emerged in North America in the concept of "transdisciplinary science" in broad areas such as cancer research. It is a collaborative form of "transcendent interdisciplinary research" that creates new methodological and theoretical frameworks for analyzing social, economic, political, environmental, and institutional factors in health and wellness (see Hall et al., this volume).

The third trendline is akin to critical ID. Transdisciplinarity is not just "transcendent" but also "transgressive." In the 1990s, TD began appearing more frequently as a label for knowledge formations shaped by critical imperatives in humanities, critiques of disciplinarity, and societal movements for change. Tracking the history of ID in Canadian Studies, Jill Vickers (1997) linked TD and "antidisciplinarity" with movements that reject disciplinarity in whole or in part, while raising questions of sociopolitical justice. Examples include women's, native/aboriginal, cultural communications, regional, northern, urban, and environmental studies. Antidisciplinary positions have also moved beyond the academic sphere, favoring materials in ways dictated by students' own transdisciplinary theories, cultural traditions, lived experience, and connotations of "knowledge" and "evidence."

The fourth trendline prioritizes problem solving. It was evident in the late 1980s and early 1990s in Swiss and German contexts of environmental research. By the turn of the century case studies were reported on an international scale and in all fields of human interaction with natural systems and technical innovations as well as the development context. The core premise is that problems in the *Lebenswelt*—the lifeworld—need to frame research questions and practices, not disciplines. This connotation is strong in projects, such as Global TraPs (Global Transdisciplinary Processes on Sustainable Phosphorus Management), and in groups such as td-net (Network for Transdisciplinary Research). Co-production of knowledge with stakeholders in society is a cornerstone of this trendline, realized through mutual learning and a recursive approach to integration (see also Pohl et al., this volume).

The fourth trendline also intersects with two prominent concepts in the discourse of TD—"postnormal science" and "Mode 2 knowledge production." They stand in striking contrast to the intellectual climate of the 1970 OECD seminar, shaped by the organizing languages of logic, cybernetics, general systems theory, structuralism, and organization theory. Postnormal science is associated with TD because it breaks free of reductionist and mechanistic assumptions about how things are related and systems operate. "Unstructured" problems are driven by complex cause–effect relationships, and they exhibit a high divergence of values and factual knowledge. Hence, they are associated with the concept of "wicked problems" (see Bammer, this volume.)

Gibbons et al. (1994) also proposed that a new mode of knowledge production has emerged. Mode 1 is characterized by hierarchical, homogeneous, and discipline-based work; Mode 2 by complexity, nonlinearity, heterogeneity, and TD. New configurations of research are being generated continuously, and a new social distribution of knowledge is occurring as a wider range of organizations and stakeholders contribute skills and expertise to problem solving. Gibbons et al. initially highlighted instrumental contexts of application, such as aircraft design, pharmaceutics, and electronics. Subsequently, though, Nowotny et al. (2001) extended Mode 2 theory to argue that contextualization of problems requires participation in the

agora of public debate, incorporating the discourse of democracy. When lay perspective and alternative knowledges are recognized, a shift occurs from solely "reliable scientific knowledge" to inclusion of "socially robust knowledge."

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3.6 The Reportage of Change

National reports are important barometers of change. The 2005 *Facilitating Interdisciplinary Research*, published by the National Research Council (NRC) in the United States, identified four drivers of interdisciplinarity today:

> (1) the inherent complexity of nature and society
>
> (2) the desire to explore problems and questions that are not confined to a single discipline
>
> (3) the need to solve societal problems
>
> (4) the power of new technologies
>
> (Committee on Facilitating Interdisciplinary Research, 2005, pp. 2, 40).

Drivers (1), (2), and (3) are not new. They have intensified, however, in recent decades. Driver (3) escalated with mounting pressure on universities to solve "real-world" problems, and driver (4) is propelled by the expanding power of generative technologies such as magnetic resonance imaging and advanced computing power for sharing large quantities of data.

The growth of interdisciplinary fields also has implications for typology. After evaluating the methodology of classifying research-doctorate programs, members of a 2003 NRC study recommended increasing the number of recognized fields from 41 to 57, renaming biology "life sciences" while including agricultural sciences, and listing subfields to acknowledge their expansion. Mathematics and physical sciences, the authors added, should be merged into a single major group with engineering. Their final 2009 report highlighted life sciences while adding a field of "biology/integrated biomedical sciences" and noting the expanding fields of public health, nursing, public administration, and communication. In addition, Appendix C called attention to emerging fields of bioinformatics; biotechnology; computational engineering; criminology and criminal justice; feminist, gender, and sexuality studies; film studies; information science; nanoscience and nanotechnology; nuclear engineering; race, ethnicity, and postcolonial studies; rhetoric and composition; science and technology studies; systems biology; urban studies and planning (Ostriker & Kuh 2003; Ostriker et al. 2009).

In 2010 a Panel on Modernizing the Infrastructure of the National Science Foundation's Federal Funds for R&D Survey called further attention to the problem of outdated classifications. The R&D Survey provides data on spending and policy in the United States. However, the taxonomy for fields of science and engineering had not been updated since 1978. The terms "typology" and "taxonomy" are often used interchangeably, but typology is technically conceptual in nature and "taxonomy" is an empirical ordering based on measurable characteristics. The methodology of measurement in the R&D survey was outdated, failing to capture increases in the multi- and interdisciplinary character of science. Also, activities were lumped into a large category of "not elsewhere classified" that includes new subfields, emergent fields, established interdisciplinary fields, cross-cutting initiatives, problem-focus areas, and the amorphous designation "other." In their final report, the Panel recommended capitalizing on new technologies to
p. 32 federate, navigate, and manage data while citing the ↳ National Institutes of Health Research Condition and Disease Classification (RCDC) database as a model of a bottom-up approach to taxonomy and permitting users to construct crosswalks among categories.

A final report accounts for new horizons of research and the growing momentum for TD. The 2014 NRC volume *Convergence: Facilitating Transdisciplinary Integration of Life Sciences, Physical Sciences, Engineering, and Beyond* defined convergence as an "expanded form of interdisciplinarity" that fosters a higher level of synthesis connoted by TD (Committee on Key Challenge Areas for Convergence and Health 2014). The report positioned convergence historically as a stage beyond two earlier "interdisciplinary" revolutions of molecular and cellular biology and of genomics. Convergence represents a new stage in bringing together bodies of specialized knowledge to constitute "macro" domains of research activity that generate ideas, discoveries, tools, and methodological and conceptual approaches. Tangible outcomes include tissue engineering, advances in cognitive neuroscience, and improved energy storage for securing food supplies in a changing climate. Convergence advances basic research but it also leads to new inventions, treatment protocols, and forms of education and training while fostering partnerships among academic researchers and stakeholders in private and public sectors. In prioritizing product development and speeding up translation of findings from the scientific bench to bedside, convergence does not just blur the boundaries of the academy, industry, and government. It erases them, while aligning ID and TD with academic capitalism.

Reflecting on the current discourse of ID and TD, Weingart identified a common topos among claims for new modes of knowledge production, postnormal and postmodern science, and newer forms of inter- or transdisciplinary research. They are all oscillating between empirical and normative statements, reinforcing democratic and participatory modes while resounding the theme that triggered escalation of ID in higher education reform during the 1960s. Now, however, claims are situated in the context of application and involvement of stakeholders in systems that are too complex for limited disciplinary modes portrayed as too linear and narrow for "real-world" problem solving. New TD and counterpart ID forms, though, are not without their own "blind spots," including failing to recognize opportunistic dimensions of both presumably "internal" academic science and strategic research for nonscientific goals. Moreover, theoretical claims are frequently overstated. Mode 2, postnormal science, and other schemes, Weingart contended, look at phenomena only on the surface, describing institutional changes rather than a new epistemology (2000, pp. 36, 38).

Ultimately, the question of knowledge cannot be separated from how we talk about it. Terminology is not simply a reflection of reality. It is a form of boundary work that filters and directs attention. Proclaiming that ID or TD has only one purpose—be it holism or problem solving—ignores the fact that ID is a contested discourse. One strand of problem solving, for instance, centers on collaborations between academic researchers and industrial/private sectors for innovations in product development. A different type occurs when academic experts and actors in society coproduce knowledge in the name of democratic solutions to the challenges of sustainability. Plurality does not spell cacophony, however. Terms are rhetorical signposts of continuity and change, tradition and innovation. They reassert, extend, interrogate, and reformulate existing classifications to address both ongoing and unmet needs.

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Acknowledgments

I thank Robert Frodeman and Roberto Pacheco for feedback on an earlier version of this chapter and thank Pacheco for designing the table of definitions.

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