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Boundary Discourse of Crossdisciplinary and Cross-Sector Research: Refiguring the Landscape of Science

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Abstract This discourse analysis of metaphors of the crossdisciplinary composite of inter- and trans-disciplinary research gleans in sights for science today. The first section establishes a baseline by comparing spatial images to growing use of organic metaphors in an ecology of knowledge production. Following logically from the comparison, the second reflects on metaphors of exchange and transaction in trading zones, transaction spaces, and third spaces, then addresses implications for the earlier exemplar of Mode 2 knowledge production. The third section considers the current exemplar of convergence as a new dynamic of fundamental and applied research then challenges the premise translation is a one-way transfer and application of findings from one domain to another, thereby recognizing complexity of relational capital, platforms as sites of collaboration, and ensuing tensions. The fourth reflects a widespread tendency to map domains of knowledge, building on Sheila Jasanoff's cartographic metaphor of Science, Technology, and Society Studies as an archipelago and broader implications for the nature and status of interdisciplinary fields. The fifth section weighs the balance of disciplinarity and interdisciplinarity, questioning the premise of a New Disciplinarity reinscribing a disciplinary home versus transversal flow and flux. The sixth recognizes growing momentum for decolonizing crossdisciplinarity, including the role of lay, traditional, and Indigenous knowledge in fostering a transdisciplinary science of sustainability. The seventh closing section reflects on preceding metaphors against the backdrop of a century of developments that have made interdisciplinarity and transdisciplinarity part of the fabric of science today, though more often in incremental ways than radical refiguration.

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Boundary discourse is pervasive in literature on "crossdisciplinarity," a composite term for both "interdisciplinarity" (ID) and "transdisciplinarity" (TD). It unfolds in oral and written communications, ranging from conversations of specialists from different disciplines collaborating on a single project to formation of interlanguages in new fields. Metaphors have also long been recognized as explanatory tools in science. A metaphor is a figure of speech that signifies defining qualities of an idea or an entity. Well known examples in science include Maxwell's demon, Schöredinger's cat, Einstein's twins, Kekule's snake biting its own tail, and neurons imagined as trees with branches. More broadly, Mathias Friman contended "Today, many scientists wield the rhetoric of interdisciplinarity," adding "Almost all scientists want to be associated with boundary crossing and creating new knowledge" (2010: 5). Friman did not document the extent of associations, but he recognized a widespread belief that science today is increasingly interdisciplinary. This process unfolded over the course of the 20th century though in the early 1970s Erich Jantsch observed, in the first major book on interdisciplinarity in universities, "The boundaries of disciplines, their interfaces, and interrelationships no longer correspond to an *a priori* system of science" (1972: 103). Writing in the same book, Jean Piaget (1972) also cited the subjective nature of boundaries between, for example, chemistry and physics, while adding the very principle of interdisciplinarity contradicts the premise of natural boundaries. In subsequent decades, a growing number of researchers and educators also contended that boundaries of knowledge production were increasingly blurring. The ubiquity of boundary discourse, then, is not surprising. This article employs discourse analysis to identify patterns of argument about inter- and trans-disciplinarity in written texts, using metaphor as an index of underyling assumptions about their nature and purpose as well as implications for science today. This genre of scholarship does not necessarily follow the structure of reporting on a scientific experiment or an investigation, typically moving from an Introduction to Methods and Results then Discussion and a Conclusion. Expository essays tend to present, to interpret, and to evaluate explanations and evidence, moving from an introduction to expansion of a core argument, and finally a conclusion. The core argument in this case–that spatial and ecological metaphors are complementary rather than oppositional–builds on Michael Winter's (1996) exploration of specialization, territoriality, and jurisdiction in the political economy of knowledge. The principle of selection for clusters of metaphors in sections of this article follows. State-of-the-art reports and handbooks provide an informed basis for understanding the relationship of spatial and ecological images, supported by other authoritative literature on boundary crossing.

The first section establishes a baseline by comparing images of a landscape demarcated by turf and boundaries to organic metaphors that reflect crossfertilization and permeable borders, illustrated by examples in physical and biological sciences. The second follows logically from Winter's interplay of spatial and ecological images, focusing on the cluster of exchange and transaction in trading

zones, transaction spaces, and third spaces where differences are navigated and mediated, with implications for the earlier exemplar of Mode 2 knowledge production. The third section then considers the contemporary exemplar of convergence as a new dynamic of knowledge production and challenges the premise that translation is a one-way transfer and application of findings from one domain to another, highlighting instead the complexity of relational capital, platforms as sites of collaboration, and ensuing tensions. The fourth reflects a widespread tendency to locate domains of knowledge by mapping them, building on Sheila Jasanoff's cartographic metaphor of the field of Science, Technology, and Society Studies as an archipelago and broader implications for the nature and status of interdisciplinary fields. The fifth section then reflects on the balance of disciplinarity and crossdisciplinarity, questioning the proposition of a New Disciplinarity that reinscribes a disciplinary home by exposing the flow and flux of liminal spaces that foster trasversality. The sixth moves beyond the academic sector to increasing momentum for decolonizing crossdisciplinarity, including the roles lay, traditional, and Indigenous knowledge play in fostering a more inclusive transdisciplinary science of sustainability. Finally, the seventh section reflects on the preceding overview of metaphors, read against the backdrop of a century of fundamental and applied inter- and trans-disciplinary developments that have produced a rich array of structures and strategies. They have become part of the fabric of science today, but more often in incremental ways than radical refiguration beckoned in metaphors of revolution and transformation.

Table 1 provides thumbnail definitions of the core concepts, and throughout the article metaphors are italicized on first mention to highlight their ubiquity, but not thereafter.

The Changing *Landscape* and *Ecosystem* of Science

Spatial metaphors of geopolitics accentuate *boundaries* and *borderlands* of disciplinary *domains, territories,* and *fiefdoms* demarcated by *turf* and *silos*. Thus they align with Michel Foucault's (1972) conception of a boundary as an aspect of *regimes of power* that make *jurisdictional* claims. Increased crossdisciplinary

Table 1 Crossdisciplinarity

Interdisciplinarity is typically associated with integration of methods, tools, concepts, theories, and/or information from existing disciplines. Sometimes they result in a new community of practice or field, also dubbed an interdiscipline. More often, though, they take the form of borrowing across disciplines, a solution to a particular complex problem, or an answer to a complex question.

Transdisciplinarity was traditionally associated with the historical quest for unity of knowledge but in the latter half of the 20th century became aligned with new synthetic paradigms that transcend existing disciplinary approaches, including general systems theory, feminist theory, post/structuralism, and sustainability. It also became a descriptor of team-based healthcare, a label for synoptic disciplines such as philosophy and geography, a new transcultural theory based on the worldview of complexity in science, and co-production of knowledge by academics and stakeholders in society to address real-world problems.

(Klein 2017, 2021)

activities, however, have challenged static spatial images of knowledge production. Authors of a state-of-the-art report on *Facilitating Interdisciplinary Research,* for example, contended integrating knowledge from multiple areas of expertise has been apparent throughout the history of scholarship on science. However, they characterized research today as evolving continually beyond disciplinary boundaries. They still invoked spatial metaphors, associating interdisciplinarity with *breakthroughs* at a peripheral *frontier fringe* or *cutting edge* of disciplines. However, the four major drivers of interdisciplinarity they identified indicate it is also occurring within their cores. The first–the inherent complexity of nature and society–is evident in scientific research ranging from the microbe and body to the earth and ultimately outer space. The second–the desire to explore basic research problems at *interfaces* and *interstices* of disciplines–is aligned with cross-secting questions and problems and in some cases new interdisciplines, such as biochemistry and molecular biology. The third–the need to solve societal problems–has put mounting pressure on the academy to *marshal resources* to grapple with global challenges such as climate change, disease, inequality, and conflict. The fourth–the stimulus of generative technologies–is also producing tools that cross boundaries of their initial design, sometimes becoming so *assimilated* they are not recognized as *foreign* to borrowers' home disciplines: including electron microscopy, X-ray crystallography, and spectroscopy that were developed in physical sciences (NASEM 2005).

The four drivers also align with dynamic properties of knowledge production revealed in Winter's (1996) exploration of specialization, territoriality, and jurisdiction in the *political economy* of knowledge. While acknowledging spatial images, he also noted that *organic* models compare intellectual movements to processes in *ecology* and the evolution of plant and animal species, thereby accentuating *crossfertilization*, *generation*, *interrelation*, and *hybridization*. Yet, rather than dichotomizing spatial and organic metaphors Winter proposed that environment and organism are not inherently opposed. The English word "ecology," he recalled, derives from a Greek word *oikeos* meaning "household" in the sense of both human *settlement* and *interweaving* fields of social action (1996: 343). Verbs associated with *oikeos* suggest not only *inhabiting* and but also processes of *managing*, governing, and *controlling*. Moreover, Winter added, both social groups and their environments are not only territorial but also *competitive* and *expansionist.* They *exploit* resources to create new life forms and settlements. Other metaphors also depict crossdisciplinarity in a mix of spatial and organic properties, including a *web,* a *network*, and a *system*. Activities associated with the three images are often deemed *nodes,* but individuals and groups move between them. So do methods and tools as well as concepts and theories. In another famous image of interdisciplinarity, Donald Campbell (1969) still invoked a spatial metaphor of fields as overlapping *fish scales* that leave gaps to be filled. However, J. Linn Mackey (1995) subsequently proposed a more radical image of *fractals* to highlight *slippage, dispersion*, and an epistemology of *deconstruction* lacking closure. Metaphors of *crossroads* and *trading zones*, in turn, signify sites where *exchange* and *transaction* occur. And, in his classic book on disciplinarity, entitled *Academic Tribes and Territories,* Tony Becher (1990) likened disciplines to individual *cells*

in a state of flux. They subdivide and recombine, changing shape and disposition. Some even exhibit an *anarchic* tendency to appear allied with counterparts in other domains. More broadly, Gabriele Bammer observed disciplines "evolve, expand, merge, contract and disappear," rendering the relationship of disciplinarity and interdisciplinary research "complicated and untidy" (2012: 14). Of added signifiance, in the updated version of Becher's book his co-editor Paul Trowler (2001) joined in citing external forces that belie the image of the academy as an *ivory tower*. The metaphor of a *Triple Helix* of the academy, industry, and government highlights interactions across sectors of society, a prominent connotation of transdiscipinarity today though not in this case including members of civil society. In particular regard to science, two chapters in the 2017 *Oxford Handbook of Interdisciplinarity* reinforce the belief interdisciplinarity has become a prominent feature of science today, while acknowledging cross-sector involvement.

Accounting for physical sciences, Robert P. Crease echoed others in arguing interdisciplinary research and collaboration is "surely as old as science itself" (2017: 71), though the core term did not appear until the early 20th century. However, he recounted, early projects often took the form of simply applying theoretical or experimental techniques from one field to another. Or, a researcher in one discipline might work at the frontier of another. More complex crossfertilizations, however, emerged by the early 20th century, including developments that led to new fields of radiation science and cybernetics. Crease also noted chemistry was frequently a "principal ingredient" in other fields, such as biophysics engineering, biology, medicine, and cybernetics (2017: 72). Discovery of the molecular structure of DNA in 1953 was a major event in the histories of both science and interdisciplinarity. New work in quantum mechanics and expansion of computing power made interdisciplinarity in Crease's assessment "all but inevitable" (p. 75). And, it is now common in fields such as bioengineering, biophysics, and nanoechnology. Hence, he concluded, it has become routine in physical sciences, though beliefs range from the view that *permeation* of boundaries signals a process of gradual change to a *revolution* in knowledge production to outright *erosion* of disciplinary boundaries. Furthermore, Crease added, although molecular biology was increasingly institutionalized as a domain it raised concern about biology *colonizing* physics and chemistry, a threat often expressed elsewhere in the geopolitical metaphor of *imperialism*. Transdisciplinarity was not a primary topic in Crease's account, but he did acknowledge cross-sector engagement of stakeholders can be considered "transdisciplinary," in this instance involving a *nexus* of scientists, administrators, politicians, evaluators, lawyers, and business personnel.

Accounting in turn for biological sciences, Burggren, Chapman, Keller, Monticino, and Torday did not mention transdisciplinarity. However, they defined them as "fundamentally shaped by its interdisciplinary activities" and "constantly shifting as new technologies and theories arise, evolve, and mature and–sometimes—fade away" (2017: 101). Hence, they acknowledged that disciplines change, while here too affirming claims interdisciplinarity is long-standing. The authors cited both intellectual and pragmatic ideas and techniques in biological sciences linked to medicine, chemistry, engineering, and mathematics. Relationships of biology and medicine, for example, led them to declare the two have been *"interwined"*

for millenia, but they noted biologists are now using new computational algorithms engineers developed to generate predictive models of complex biological processes and systems including population and disease, while also advancing the growing field of bioinformatics propelled in significant part by the fourth driver in the report on *Facilitating Interdisciplinary Research*. Collaborations with physicians and engineers are producing innovations in regenerative medicine, such as replacement tissues and organs. And, genetics, molecular biology, and physiology have merged in genomics, resulting in scientific discoveries being translated into new protocols and practices in healthcare. To no surprise, then, synergies that emerged from interactions and integrations have resulted in the plural "biological sciences" rather than a singular discipline of "biology." Forecasting the future, Burggren, Chapman, Keller, Monticino, and Torday predicted biological sciences will continue to operate in an interdisciplinary *cycle* spawning new interdisciplines such as biochemistry, which they deemed "[o]ne of the oldest and most productive interdisciplinary amalagamations with the life sciences" (p. 104). Moreover, it continues to evolve. Generally speaking, though, outcomes range from short-term interactions to formation of domains where new developments may reenter the cycle. Or, their impacts may *disperse*, influencing repertoires of methods and techniques in other communities of practice. Or, *synergies* they foster might never gain *traction.* The metaphor of a *cycle*, then, is not deterministic. The authors also acknowledged interdisciplinary collaboration is "not without pitfalls and impediments, from both an individual and an institutional perspective" (p. 101). Cognitive, behavioral, and emotive factors impede collaboration, as well as challenges of communicating across specialized vocabularies and developing common understanding despite differences in disciplinary approaches and even different meanings for the same words. Yet, Burggren, Chapman, Keller, Monticino, and Torday concluded biological sciences will continue to produce new approaches and enclaves, underscoring the generative nature and power of exchanges and transactions.

In establishing a baseline, the prior section depicted interactions that challenge the stark dichotomy of spatial and organic metaphors. Yet, the question of where and how crossdisciplinary and cross-sector research are located still arises. Typical sites tend to be projects and programs, centers, and sometimes new communities of practice that also take institutional root as educational programs of interdisciplinary studies. Completely autonomous programs, centers and institutes, and entire institutions are more rare. Viewed in spatial terms, each site is a *trading zone* where speakers of different languages interact. *Bilingualism* is a popular metaphor of communication across cultural and disciplinary boundaries. However, mastery of two disciplinary languages rarely occurs. Pidgin, creole, and interlanguage are more accurate characterizations. In science studies the metaphor of a trading zone is often associated with Peter Galison's (1997) borrowing of the concept from anthropology to describe how dissimilar cultures establish common ground. When bartering fish for baskets, to illustrate, participants have different meanings for objects they are exchanging but are still able to engage in transactions by establishing equivalent values. Extending the concept to science and technology, Galison cited collaboration across schools of thought within physics and engineering. Developing radar, for instance, required bridging physicists' theory with engineers' mechanics. Pidgin and

creole, though, also have a long etymological lineage in linguistics. Pidgin is a technical term for an interim form of communication that constitutes a *trade* language between speakers of different languages, evoking both anthropological and linguistic connotations of exchange and transaction. In contrast, a creole is a more established form of communication that is transmitted to future generations. Every pidgin does not inevitably become a creole, however. Galison cited iatrogenics, which did not join Newtonian mechanics and physiology and even disappeared after the 18th century. Subsequently, despite hopes of nuclear scientists, engineers, and health physicists, neutronics befell a similar fate. Yet, by the early 21st century, Galison surmised nanoscience "loomed as a major continent in the map of the sciences" (2010: 34). Even so, he questioned underlying assumptions about fixity, contending science is always in flux. In addition to a trading zone, other images affirm Winter's premise that environment and organicism are not inherently opposed, prominent among them concepts of *transaction space*, *borderline space*, and *third space.*

Michael Gibbons (2008) contended the metaphor of a transaction space shifts the concept of translating findings from one domain to another to *dialogue* between them. Homi Bhabha's (2004) concept of a productive borderline space also conceives of location as a *liminal* sphere with potential to realign and even transform traditional boundaries. And, Edward Soja's (1996) notion of a third space as an in-between or hybrid site illustrates simultaneity of spatial and ecological dimensions. The everyday example is a pub or club where individuals from first and second spaces of home and a workplace or school come together for a common purpose. Extending the concept to transdisciplinary research, Vilsmaier et al. (2017) emphasized Bhabha's conception of third space as a multi-layered physical, cognitive, and social site that constitutes a new topos (rhetorical theme or topic) in the landscape of institutions. By facilitating movement beyond existing structures, it raises the possibility of *renegotiating* identities and meanings in a bidirectional dynamic of difference and integration. From a longer historical view of knowledge formations, Peter Weingart cited shifts with implications for continuing use of spatial metaphors. During the 17th and 18th centuries the complexity of managing growing amounts of data meant "The traditional methods of information processing, the classification and spatial ordering of knowledge, had to be given up" (2010, p. 5). Echoing Wolf Lepenies (1976), Weingart (2010) explained that spatially conceived classification systems of natural history were replaced at the turn of the 18th and 19th centuries by temporalization. As a result, thinking in terms of temporal development became a new technique of systematizing, processing, and ordering knowledge. He also cited a shift relevant to both the metaphor of a Triple Helix and a cross-sector connotation of transdisciplinarity. A growing proportion of funding from industry led to increases in transitory networks. External involvement, Weingart added, even promoted a belief that the university has lost its monopoly on knowledge production. This claim lies at the heart of Gibbons, Limoges, Nowotny, Schwartman, Scott, and Trow's (1994) Mode 2 theory of knowledge production.

In contrast to Mode 1–based on hierarchical, homogeneous, and discipline-based work–the defining traits of Mode 2 are complexity, non-linearity,

heterogeneity, and transdisciplinarity. Moreover, Gibbons and co-authors reported Mode 2 "is not being institutionalized primarily within university structures" (p. vii). Instrumental applications are occurring in other knowledge-producing institutions including governmental and corporate research labs as well as sites of aircraft design, pharmaceutics, electronics, and product development. Mode 2 theory was widely influential, to the point some heralded it as the new *raison d'etre* of science and technology. However, it met with criticism as much as applause. Weingart (2000), for one, cited overstating theoretical claims, failing to recognize the power of academic capitalism, falling short of transformation, and looking at phenomena on the surface of changes rather than developing a new epistemology. Others cited prioritizing instrumental applications at the expense of basic research, and others yet minimizing continued dominance of academic expertise and stretching the theory too thin to account for developments in humanities. Mindful of criticism, in a book aptly entitled *Rethinking Science*, Nowotny, Gibbons, and Scott (2001) extended Mode 2 theory to emphasize contextualization of problems requires participation in the *agora* of public debate. When lay perspective and alternative knowledges are recognized a shift occurs from solely reliable scientific knowledge to inclusion of socially *robust* knowledge. The metaphor of robustness in engineering connotes *fit* for a particular environment, given design parameters such as topography, climate, materials, and customer needs. In medicine it connotes strength and vigor in health. Extended to cross-sector transdisciplinarity, robustness connotes suitability for stakeholder and end-user needs. Disciplinary and professional knowledge are not jettisoned, or scientific expertise. They are placed in a larger context that requires balancing forms of expertise for a given purpose. From a historical perspective, challenges to the expert/lay dichotomy were not new, either. They were preceded by theories of deliberative democracy in agriculture, calls for co-management of the environment, and new transdisciplinary approaches such as participatory action research. Yet, stakeholder engagement is heightened in current discourse of transdisciplinarity that prioritizes pressing societal problems. Current momentum for *convergence* is a more recent exemplar of knowledge production. Comparable to other concepts, it has multiple connotations. The term is a label in higher education for coherence across separate academic units of a campus with the aim of reducing fragmentation by targeting common themes, including in some cases selected grand challenges of the day. Yet, the discourse of convergence also beckons a new mode of scientific research aligned with transdisciplinarity.

Convergence, Translation, Platforms, and Tensions

The report of a 2018 workshop on *Fostering the Culture of Convergence in Research* cited a number of related initiatives across the world. The keyword has been incorporated into the renamed OECD Working Party on Biotechnology, Nanotechnology and Converging Technologies. The Japanese World Premier International Research Center Initiative linked the concept with breakthroughs from disciplinary *fusion*, and the Seoul National University and the Gyeonggi

Provincial Government of South Korea set up Advanced Institutes of Convergence Technology. And, in the US, the concept is being aligned with transdisciplinary research on complex scientific and societal challenges. Participants in the 2018 workshop cited a wide range of examples: including efforts to understand complex biological systems as well as applications in healthcare, manufacturing, new fuels and energy, and food supplies (NASEM 2019). The underlying metaphor is a *merger* of ideas, approaches, and technologies from diverse fields in a network of cross-sector partnerships. Both the 2018 workshop and a 2014 state-of the-art report issued by the US-based National Academies were inspired by Sharp and Langer's (2011) White Paper deeming convergence a third revolution. The first interdisciplinary revolution in their timeline was the field of molecular and cellular biology and the second genomics. These developments advanced understanding of biological processes. However, convergence beckons a framework for problem solving the 2014 report called an "expanded form of interdisciplinarity" (pp. 20–21). Convergent thinking, Sharp and Langer added, is advancing science through integrated partnerships in the ecosystem of research. The underlying dynamic is a process of divergence and convergence. Roco, Bainbridge, Toon and Whitesides (2013) explained it occurs when a new technology or a set of them yields components that are combined and recombined, spinning off new applications. Convergence also brings together knowledge from multiple fields and ideas to produce new macro-domains of research comprised of new inventions, innovations, treatment protocols, education and training.

However, here too, limits appear. Roco, Bainbridge, Toon and Whitesides (2013) cautioned a new broad-based knowledge network for convergence has not materialized or inclusion of all stakeholders. Authors of the 2018 workshop summary also reported major federal agencies such as the U.S. Department of Transportation were missing from conversations, even though technologies such as artificial intelligence are increasingly being integrated into vehicles and transportation systems are being rethought to address needs of aging populations and smart cities (NASEM 2019). The question of which voices are heard in research collaborations follows. The 2014 report aligned convergence with translation of scientific research directly into professional practices. So did a report the following year on *Enhancing the Effectiveness of Team Science*, reinscribing the connotation of a one-way flow from science *to* society. In some cases community members might be involved in research projects (NASEM 2015). Yet, Akkerman and Bakker (2011) explained, *transfer* is mostly about one-time and one-sided transitions, while boundary crossing is ongoing with two-sided actions and interactions. Furthermore, transfer literature treats differences as problematic, to be overcome or avoided. In contrast, boundary literature values them as resources for dialogue and learning. Dvora Yanow (2004) further admonished translators are not *passive conduits,* while Best, Hiatt, and Norman (2006) tracked related developments in evolution of transdisciplinary and translational health research (cited in Neuhauser, Richardson, Mackenzie, and Minkler 2007). Since World War II increasing attention has been paid to social, psychological, and cultural factors involved in disease. Yet, from 1960 to the mid-1990s dominant models

of translational health research were linear and depicted knowledge as a product of passive transfer from researchers to users in two phases: from basic research to clinical practices and from clinical practices to community applications. Prompted by anomalies in conception of knowledge transfer and deeper understanding of social interactions, the focus shifted to exchange, accentuating relationships of collaborators and local cultures, economies, and settings. A subsequent third-generation model emphasizes integration in a systems approach to interwoven priorities, cultures, and contexts. As a result, relationships at all levels become crucial to accessing and integrating knowledge. A number of new frameworks are also being developed, notable among them integration and implementation sciences to grapple with real-world problems (Bammer 2005) and transdisciplinary action research (Stokols 2006). In recognizing new spaces are not isolated, these and other frameworks render *relationality* a descriptor of knowledge production while underscoring variability of boundaries. In another aptly entitled book, *Redrawing the Boundaries*, Greenblatt and Gunn emphasized their variability.

Greenblatt and Gunn explained boundaries "can be crossed, confused, consolidated, and collapsed; they can also be revised, reconceived, redesigned, or replaced." However, they cannot be entirely abolished. The authors were focusing on the field of literary studies, but their observation applies generally. The task then becomes "figuring out what boundaries enclose and exclude; whether they are drawn in bold, unbroken strokes or as a series of intermittent, irregular dashes" (1992: 4). Comparably, the metaphor of a *platform* would seem at first glance to reinscribe a monolithic notion of spatial location. A platform is usually associated with a fixed structure on which to stand or to sit, a well defined set of principles or positions, or the architecture of a computer operating system. However, in crossdisciplinary work it signifies a transaction space where new relationships emerge and where boundary lines are not only crossed but sometimes redrawn. In a case study of sustainable landscape management, to illustrate, Hindenlang, Heeb, and Roux (2008) defined cross-sector stakeholder platforms as loosely structured social networks for creating *relational capital* in transdisciplinary research. In this case, representatives of different action systems came together for a shared purpose: including foresters, hunters, farmers, nature conservationists, and in two projects academic scientists. Mutual learning between practitioners and scientists was key to resolving conflicts that often arise when different approaches are brought together, requiring negotiation of common meanings and a shared purpose. In a different study of research networks Boix-Mansilla, Lamont, and Sato (2016) compared markers of and conditions for interdisciplinary collaborations at the Canadian Institute for Advanced Research, MacArthur Foundation, and Santa Fe Institute. Their findings suggested the concept of shared cognitive-emotional-interactional platforms is a heuristic tool for capturing relationality. The authors also likened the cognitive dimension to the metaphor of a trading zone in science studies. Yet, they explained emotional and interactive qualities come into play as well, including interpersonal tensions and feelings of being disrespected and mistrusted. Following suit, participants in other projects have likened platforms that are sites of collaboration to a *sandbox, safe haven,* and *reunion*. Yet, *tensions* still arise. In yet another study, Salmela, MacLeod, and Munck (2021) identified three types of tensions in alternative platforms for collaboration. The

occasion was an experiment to incentivize interdisciplinarity at a small Nordic university specializing in green technology. In order to incentivize interdisciplinarity the university decided to reallocate internal research funds for at least five years, inviting researchers from at least two of the institution's three schools to work together on a proposed problem or goal. However, the authors reported, three kinds of tensions arose.

The three tensions arise in other areas as well. Epistemic tensions, Salmela, MacLeod, and Munck explained, arise from conflicts in disciplinary standards and values. Structural tensions are linked to academic rewards and funding. And, emotional tensions occur when identity and status in a discipline conflict with demands of working across boundaries. Interviews of researchers revealed strains around allocation of resources, divisions of labor, relations between disciplines, academic careers, and choices about scientific output. The authors deemed Platform B the most successful of the three they studied in working toward interdisciplinary integration. It emerged from previous collaborations of engineers and natural scientists who were developing simulations of construction vehicles to replicate users' experiences. Business researchers joined them to help design simulation technology. However, strains arose around participation and epistemic payoff for business faculty. Despite overall positive views, divisions of labor and disciplinary relations continued to be sources of tension. Comparable to Boix-Mansilla, Lamont, and Sato's findings about emotional dimensions, business researchers felt they were considered of lesser status, a feeling often likened to *pecking orders* in *status hierarchies.* One informant recalled an engineering group wanted to reserve most seed funding for itself, requiring the university to intervene by allocating funds more evenly. Nonetheless, business specialists still sensed they lacked priority and status. One interviewee felt disregarded and business faculty relegated to data scientists lacking relevant or significant theoretical knowledge for engineering. Interview data also indicated researchers prioritized acquiring funds, not interdisciplinarity. Structural tensions, in particular, affected views of academic career advancement, creating an *undertow* of participation comparable to the *drag* co-chairs of the 2005 NASEM report on interdisciplinary research lamented. In short, platforms foster alternative practices but do not by themselves transform the reward system and tend to be short-term. The metaphor of *mapping*, then, raises the question of where they are located.

Mapping the Archipelago

The metaphor of mapping is ubiquitous because the impulse to locate is widespread: whether talking about elements in a mathematical set, positions in a double helix, parts of the human brain, the locus of celestial objects in outer space, or land masses and their partitions. Inevitably mapping is also a popular way of locating domains of knowledge in the academic world, where disciplines have long occupied pride of place. In an account of Science, Technology, and Society Studies (STS), Sheila Jasanoff suggested that two ideal-typical maps underlie the interdisciplinary field. In one, all disciplines are lined up tightly, analogous to a map of the *contiguous* United States with shared boundaries and no gaps between states. The other map is analogous to the Indonesian *archipelago*, depicting disciplines as "idiosyncratically

bounded islands scattered across a sea of ignorance, with unexplored waters between them" (2017: 174). On the first map, a new interdiscipline emerges primarily through exchanges of scholars from established disciplines. On the second map, an interdiscipline is an *autonomous formation* responding to societal concerns or novel topics. Jasanoff concluded STS looks more like the latter than the former: akin to charting new territories between *islands* of disciplined thought in *high seas of the unknown*, rather than a program of *interstate highway construction* linking states. Yet, she concluded, after roughly 50 years and wide recognition of the field's accomplishments it is still weakly institutionalized in upper reaches of the academy. STS interests were often located as *subsets* of traditional departments and even autonomous programs emphasized history, philosophy, or public policy and applied or basic research. Individuals also defined themselves as anthropologists, historians, sociologists, or political scientists. Yet, Jasanoff cautioned, a conventional approach to classification fails to problematize the taken-for-granted nature of disciplinary boundaries. By challenging the assumption that disciplines are coherent and unified, STS enters *troubled* and *uncertain* territory. Its future, she contended, depends on *redrawing* the map of disciplines to demonstrate they are all islands of happenstance in *unmapped waters*. STS could then claim a space as a *fertile* territory without threatening other parts of the archipelago. More generally, Jasanoff urged, all interdisciplinary fields need to establish credible *relations* with their objects of study and to assert a stronger sense of their boundaries and missions. They also require organization for survival and continuity, demarcating themselves from neighboring territories while creating markers of originality, quality, progress, and contributions to knowledge. Doing so involves them in boundary work but recognizes at the same time even their borders are permeable, not rigid and closed. Beyond particular fields, the concept of interdisciplinarity may also be likened to an archipelago, with islands of definition.

Reflecting on its future, Robert Frodeman (2017) concluded interdisciplinarity has functioned as a boundary object with different meanings at different times for different groups. Hence, it has been a *portmanteau* word for anything more-than-disciplinary. Yet, extensions beyond epistemological priorities have advanced socio-political concerns linked with the imperative of problem solving. Expansion beyond Hegelian-like syntheses of knowledge, he added, is calling attention to co-production of knowledge across sectors, though not always in the name of interdisciplinarity. Thus, Frodeman asked whether we may have reached *peak* ID in the political economy of knowledge, comparable to peak oil as "an often depicted but never-quite-reached point of decline" (5). The concept might still become central to transforming the 21st-century university but, he reported, politicians and citizens are talking instead about "impact," "accountability," and "relevance" (5). The challenge then becomes whether to adopt other goals than epistemic synthesis and methodological integration. Moreover, structures that both inter- and trans-disciplinarity were intended to render them more open retain their power. Yet, in tallying claims for both Mode 2 and TD, Weingart concluded the dominant organizational structure of disciplines remains "unfettered" (2010: 13). He forecast disciplines and multi-, inter-, and trans-disciplinary fields will continue to exist side by side. Likewise, Crow and Dabars (2017) concluded the dominant structure of academic organization

remains disciplines. They are deeply embedded and entrenched in academic culture, curbing efforts to *reconstitute* it. Co-chairs of the task force that produced NASEM's report on interdisciplinary research also acknowledged the majority of examples suggested incremental changes outnumber transformative approaches. Likewise, the 2014 NASEM report on *Convergence* highlighted incremental benefits over transformation.

The picture of boundary discourse that emerges is complex. A recent study of crossdisciplinary and cross-sector work identified their boundary work: "It encompasses acts of spanning, crossing, and bridging; processes of interacting, integrating, and collaborating; strategies of brokering, mediating, and negotiating; operations of demarcating, constructing, and refiguring; new relations of interdependence convergence; and outcomes of breaching, transgressing, and transforming" (Klein 2021: 22–23). Verbs of action dominate, underscoring dynamics of boundary crossing while raising the question of whether there is a unique logic of interdisciplinarity. Answering the question, Mathias Friman (2010) argued disciplinary logic is *monotheistic*. Even this theological metaphor, though, recognizes hierarchy of power subordinates alternative claims. Likewise, Catrin Heite (2012) portrayed a boundary as both an *expression* of power relations and governance as well as a *medium* for their maintenance. In contrast, interdisciplinary logic promotes plurality. Yet, following Scott Frickel, Friman contended boundary problems in interdisciplines hinge on "perforating existing boundaries and/or inventing porous ones" (2004: 273). Frickel cautioned an interdiscipline cannot bypass boundary work of disciplining even when advocating multiple perspectives and, taking a step further, recognizing limits of its own knowledge claims. Degrees of openness and closure vary as well, recalling Greenblatt and Gunn's exhortation to consider how boundaries are drawn, not impose a monolithic conception of them. Moreover, all interdisciplines are not the same. Mindful of Jasanoff's caveats about STS, molecular biology has attained more autonomous status than, for example, social psychology and digital humanities. The metaphor of *balance* then follows. Drawing insights from information research on ID, Carole L. Palmer contended "Interdisciplinary research requires a balance between established core knowledge and the infusion of new knowledge." As a result, many researchers have dual or multiple agendas, "building on a core research specialization as they transit into a newer hybrid area" (1999: 250). Marcovich and Shinn's concept of a New Disciplinarity would seem to parallel this view. They called the accelerating volume and complexity of scientific knowledge nothing less than "the matrix of contemporary knowledge production and communication" today (2011: 584). It is evident in the abundance of concepts, instruments, materials, and enlarged scope of questions being raised. However, Marcovich and Shinn contended disciplinary homes remain the primary referent in the balance of disciplinarity and crossdisciplinarity. Most researchers, they claimed, return "at once" to the "hub of their home discipline" (2011: 587, 602), protecting their disciplinary space, its logic and their identities.

Weighing *Balance*

The image of balance connotes equilibrium, whether establishing physical stability to avoid falling, achieving harmony between professional and personal lives, weighing costs versus benefits, or determining the relationship of disciplinarity and crossdisciplinarity. Marcovich and Shinn conceded connections, combinatorials, and transformed practices are sometimes a *spawning-ground* for new disciplines, citing examples of solid-state physics, molecular biology, nanoscale research, and climatology. Yet, they maintained, the *gravitational or centripetal force* of interdisciplinary interests does not displace a researcher's *mother tongue*. Marcovich and Shinn depicted scientists desiring contact beyond their disciplinary territories standing on a patch of the closest borderland: likening their exchanges to "shouting back and forth to each other across the dividing boundary wall" or Eric Winsberg's analogy of "hand-shaking" (2006: 590). They further likened the space of exchange to a *traffic-circle* where individuals replenish their disciplinary resources but, again, inevitably return *home*. Their representation of interdisciplinarity is also narrow, equating it only with technoscience and anti-disciplinary postmodernism. Moreover, they alleged multi-, inter-, trans-, and post-disciplinarity all aim to abolish boundaries, claiming "Advocates of interdisciplinarity prophesy the unavoidable, ultimate demise of all scientific disciplines and their replacement by a form of learning and research that fuses extant universes of materials, cognition, social groups, institutions and markets into a de-differentiated ensemble with the same goals" (p. 584). Quite the contrary: literatures on ID and TD reveal a wide range of views, from complementing disciplines to transgressing their boundaries and even transcending with new frameworks. Boundaries, though, do not necessarily disappear or discipline-based departments for that matter. All short-term research programs are not "boundarylessness" either, as Marcovich argued in characterizing their provisional nature; nor are scientists in contexts of "inter-(anti-)disciplinarity" plagued by "homelessness" (2011: 507, 585). Marcovich and Shinn further claimed the vast majority of scholarship on interdisciplinarity focuses on humanities, social sciences and arts, but overlooked numerous accounts focused on science, engineering, and medicine. Despite these distortions and omissions, though, they did describe projects as a "transversalist" combination of encounters and activities, evident in heterogeneous laboratory affiliations of partners who are engaged in numerous projects; they also likened a project to a "bundle of encounters and activities characterized by extra-territorial cognitive and materials flows escaping disciplinary codes" and putting disciplines in "relative flux" (596–597). Yet, they still tilt the balance towards disciplinary codes. In contrast, Vilsmaier et al. (2017) posited a different balance of location and flux in defining transdisciplinarity.

Vilsmaier, Brandner, and Engbers built on Pierre-Félix Guattari's (1989) conception of an ecology of knowledge as a "general deterritorialization of old societal territories, ways and customs, traditions, and self-regulating representations." Deterritorialization would be grounded in relational thinking and diastatic identities, not monadic and static entities. Guattari further contended "transdisciplinarity must become transversality between science, the socius, aesthetics, and politics"

(2015[1992]: 134). In mathematics *transversality* signifies intersections of lines and spaces. In transdisciplinary research it bespeaks crossroads leading to new connections. Balance, though, still tilts in general towards disciplinarity and academic science. Interdisciplinarity is not fully mainstreamed in the academy, and transdisciplinarity continues to be marginalized and even contested. Yet, Vilsmaier, Brandner, and Engbers' concept of "critical transdisciplinary research practice" posits a third way of addressing urgent challenges with potential for rebalancing power in the landscape of institutions and forms of knowledge. The authors join others in stipulating existing approaches are not rejected. However, their conception of complementarity elevates reflexivity and critique in cultural practices. "Culture" refers to both the famous two-cultures divide of science and humanities as well as approaches to problem solving grounded in local knowledge. Vilsmaier, Brandner, and Engbers argue the former is outmoded because of fragmentation and efforts of overcome it. The latter calls attention to new transdisciplinary spaces bridging the divide of inside and outside the academy. Moreover, they challenge past dominance of the North and the West in crossdisciplinary research, recognizing a greater diversity of voices implied but not always realized in rhetoric of co-design, co-production, and co-creation. This imperative is amplified in current momentum for *decolonizing* inter- and trans-disciplinarity.

Decolonizing

Decolonizing has become a symbol of resistance to colonial practices in not only political power but also hierarchies of knowledge and problem solving. Discourses of inter- and trans-disciplinarity dominated in the past by Northern and Western perspectives are being challenged by traditional and Indigenous ways of knowing as well as pressing social, political, and environmental needs in the Global South. Nelson Maldonado-Torres (2019) also contrasted Ethnic Studies in the North to disciplines and methods of European sciences. In doing so, he contended "'interdisciplinary' spaces that foster emancipatory or decolonial orientation are better understood as transdisciplinary" (p. 232). He cautioned, though, not all forms of transdisciplinarity carry the mandate to decolonize disciplines. Maldonado-Torres tracked the field's emergence to the 1960s, as an outcome of a Third World Liberation Front strike in the US at San Francisco State University and the University of California at Berkeley. Maldonado-Torres classified the field as a composite label for spaces of African American, Black, Africana, American Indian-Native American, Latino-a-x, and Asian American and Asian Diaspora Studies. He attributed their decolonial transdisciplinary nature to layering together social activism, artistic creation, knowledge production, and in some cases spirituality. Viewed from the particular standpoint of activism, the composite of fields under the umbrella label of Ethnic Studies constitutes a family of spaces in the academy for confronting hegemonic forms of power, in the process, Maldonado-Torres noted, mobilizing concepts of race, gender, class, and other markers of difference. On a broader plane, he equated their decolonial consciousness with border consciousness, advancing a form of transdisciplinary border thinking that conceives of boundary crossing as an intersection of differing

spheres of knowledge, action, and creation where a decolonizing subject defies rigidity of disciplines and methods. It does not reject them, however. It appropriates them as technologies for a broader project that promotes marginalized people informed by their experience and expertise. In yet another account of the field, Adán Garcia (2019) took a step further by critiquing mainstream discourse of transdisciplinarity for entanglement with colonialism, despite advocacy of multiple worldviews and reconfigurations of knowledge. He built on Emma Peréz's (1999) concept of the decolonial imaginary to account for epistemic erasure of scholars who are forging in-between spaces for reclamation and reconciliation. He also faulted the "liberal left" for failing to acknowledge critical, decolonial, and Ethnic Studies scholars. It must be said, though, fields that emerged from socio-political movements outside the academy did create more spaces for critical theory. Nonetheless, Garcia called attention to an international roster of writers who have been advancing decolonial thinking.

Jamaican-born LaRose Parris, Garcia reported, aimed to creolize humanities by engaging work of writers such as European philosopher Jean Jacques Rousseau, French West Indies scholar Frantz Fanon, and US-African Americans such as Frederick Douglass, Ida B. Wells-Barnett, and W.E.B. Du Bois. They brought attention to linguistic and cultural blending in creolization, including voices of Indigenous peoples, enslaved Africans, indentured Asian and European laborers, and European planters in the Americas from the late 15th century forward. Parris also characterized Douglass as a transdisciplinary thinker, while situating Trinidadian C.L.R. James within a transdisciplinary paradigm. US-based Ethnic Studies scholar Reiland Rabaka (2010), Garcia added, called Africana Studies a "*transdisciplinary human science* that rejects the rules of the epistemic *apartheid* of the European and European American academies" (2010: 21). And, he credited Rabaka (2017) with coining the phrase "transdisciplinary critical social theorists" to describe revolutionary thinkers and theorists who do not fit into disciplinary compartmentalizations. Garcia further described Du Bois and Guinean Amilcar Cabral as transdisciplinarians while calling attention to Chicana feminist scholars who traversed boundaries and borders of literature, concepts, and alternative worldviews. US-based Peréz and Gloria Anzaldua (1987) have highlighted complexity of hybrid identities as mestizas/os. Botswanan Bagele Chilisa (2017) has also called for a decolonial and Indigenous transdisciplinary sustainability science. African philosophies, worldviews, and history contribute alternative ways of conducting research even though they have been marginalized. Chilisa suggested an evolving discourse of Indigenous and Local Knowledge even beckons a fifth knowledge paradigm to add to the typology of postpositivist, constructivist, transformative, and pragmatic paradigms, thereby questioning academic and methodological imperialism while centering problem- and situation-driven research agendas. Indigenous research roots methodologies in cultural practices, worldviews, and values of formerly colonized societies, while elevating problem- and solution-driven agendas. Chilisa cited a combination of ethno-philosophy, philosophic sagacity, nationalistic–ideological philosophy, and professional philosophy. Ethnophilosophy, for instance, focuses on how mythical concepts, ritual practices, language, proverbs, metaphors, folklores, stories, songs artifacts, and art can guide theoretical or methodological frameworks.

Two examples of cross-sector partnerships Chilisa cited illustrate efforts to rebalance expertise for a more democratic form of scientific enquiry. The first example was a multi-epistemological example involving Indigenous Maya medical specialists from Guatemala and Western biomedical physicians in a study of cancer healing systems. Outcomes of many projects tend to be traditional academic publications and presentations, replicating their specialist languages and representations of projects. One of the results in this case, though, was a book in a local language recognizing Mayan knowledge of healing and healthy ecological relationships. Ceremonies promoting ecological sensitivity were sites where holders of Maya ILK conducted rituals elevating consciousness of and expanding insights into the healing process. The second example was a collaboration of a microbiologist with the Khoi and the Sa people. The academic researcher incorporated Indigenous and Local Knowledge by working with them to study how communities interact with medicinal plants and the role that plants play in building economies both at home and on national levels. This project also brought practices of the Khoi and the Sa to urban spaces, where many members of rural communities have migrated. These and other examples also underscore the value of traditional and Indigenous forms of knowledge in approaching complex problems. The concept of Afrikanization, for instance, has empowered Africans to be active participants in framing research topics, methodologies, and strategies, making them more equal partners in conducting research. Moreover, Afrikology is derived from a cosmology of connectedness and holism. Indigenous methodologies, Chilisa emphasized, are also relational. Third-space methodologies balance European and North American knowledge with less hegemonic approaches. Unequal power relations, she admonished, are the greatest threats to collaborations for sustainability in Africa. Decolonizing, she added, reclaims Indigenous epistemologies and methodologies for sustainability science. Yet, a final question arises. Have efforts to rebalance power and perspective actually refigured science at large?

Conclusion: *Refiguring* Science?

Interdisciplinarity has been a recognized concept since the early 20th century, appearing during the first half in conjunction with the historical quest for unity of knowledge, social science research on problems of the time, integrative models of education at all levels, frameworks for understanding national cultures such as American and Area Studies, and defense needs exemplified by the Manhattan Project to produce both fundamental and practical knowledge for a weapon of war. Over the course of the century the number of crossfertilizations and new fields arose, disciplines became more heterogeneous, and the ascendancy of transdisciplinarity fostered new conceptual and methodological frameworks as well as stakeholder-inclusive approaches to problem solving beyond interdisciplinary integration of existing specialties. As we have also seen, the concept appeared increasingly as a descriptor of science, to the degree many observers claimed interdisciplinarity had become intrinsic to the nature of scientific enquiry. Any map of the current archipelago of both inter- and trans-disciplinarity, then, would recognize a plurality of motivations, practices, and structures. All the while, state-of-the-art accounts from science-policy

bodies, funding agencies, and educational commissions continue to document acceleration of both crossdisciplinary and cross-sector work in science and its relations with social sciences as well as humanities and arts. Reports typically reinforce the importance of disciplinarity, even though problem solving has clearly gained heightened priority. For instance, while affirming the need for and role of strong disciplines, the US National Science Foundation's (NSF) current initiative prioritizing Ten Big Ideas also endorses both discovery and pragmatics for bettering the lives of all species and the planet. NSF's targeted ideas include catalyzing research in science and engineering at the frontier of humans and technology, fostering creativity and partnerships in convergence research aimed at understanding and solving complex problems, harnessing the data revolution in all areas, and conducting research in the Arctic driven by biological, physical, chemical, and social changes. And, the vision of NSF 2026s Idea Machine fronts large questions with the aim of transcending established structures and standard procedures while engaging a wider range of stakeholders beyond the academy. Although the NSF concentrates on science and technology, instead of the National Institutes of Health's mandate for biological sciences, NSF's Ten Big Ideas also include understanding the nature of life from the molecule to the biosphere (https://www.nsf.gov/news/special_reports/big_ideas/). For its part, the NIH's portfolio of interdisciplinary initiatives spans discovery and well being as well, with programs aimed at establishing research consortia and training, fostering innovation in technology and methods, and promoting multi-investigator programs (http://commonfund.nih.gov/interdisciplinary/).

Moreover, momentum is international. A 2004 report on *Interdisciplinarity in Research*, issued by the European Union's Research Advisory Board echoed widespread exhortations to prioritize complex societal problems. It also joined other accounts in declaring boundaries are increasingly blurred, while locating breakthroughs in science at boundaries and intersections of disciplines (https://ec.europa.eu/research/eurab/pdf). The League of European Universities' subsequent report on interdisciplinarity for the 21st century acknowledged exchanges between disciplines have long been part of science, but asserted it became a priority in science policy during the latter quarter of the 20th century. Following suit, management of collaborative research projects became a topic of increasing interest. The authors also contended interdisciplinarity is "essential to the evolution and refiguration of the disciplines" (Wernli and Darbellay 2016: 3). Gleed and Marchant's (2016) survey report for the Global Research Council took a step further by documenting initiatives in Africa, the Americas, the Asia-Pacific region, Europe, the Middle East, and North Africa. Taken together the authors' introduction and individual summaries also indicated interdisciplinarity is aligned worldwide with major societal challenges. Yet, although Gleed and Marchant found a "wealth of literature," they identified widespread need for an "architecture" of programs conducive to success (7, 8). Inevitably, a sense of *déjà vu* arises when scrolling through these and other reports: including reasons for increasing emphasis on ID and TD, the need for sharing successful practices, sufficient timeframes for project development and successful collaboration, design of favorable spaces, appropriate assessment criteria, training, and institutional capacity building. Most funding agencies, Gleed and Marchant added, did not have formal policies about interdisciplinary research, despite encouraging

and supporting it. Informal practices evolving through trial and error outnumbered formally embedded policies.

To conclude, the metaphor of balance has loomed large in this analysis of boundary discourse in crossdisciplinary and cross-sector research, both explicitly and implicitly. Determining a balance of forms of expertise is required whether engaging in short-term projects, working in new platforms and other sites of exchange, incorporating new practices, institutionalizing new communities of practice, or refiguring relationships between science and society at large. Doing so is a process of negotiation and mediation, not fidelity to a single perspective even if power dynamics continue to tilt balance in their direction. However, the metaphor of balance in crossdisciplinary and cross-sector work is not the classic image of a blindfolded woman evening out weights on a scale, without bias of influence. A multiplicity of influences determine selection and impact of inputs and sectoral interests. Likewise, claims vary along a spectrum from preservation of dominant practices and the system of disciplinarity to challenges to and transgressive disruption of them, and even their ultimate displacement. Echoing both Winter and Jasanoff, crossdisciplinary and cross-sector work are also located across an expanse of spaces where exchange and transaction occur. Maldonado-Torres' notion of a transdisciplinary border character further challenges stark dichotomies of not only disciplinarity versus interdisciplinarity and inter- versus trans-disciplinarity but also specialists versus generalists as well as the North and Global South. Others also join in contrasting academics versus "non-academic" or "non-scientific" stakeholders, but here too reflexivity is required. The prefix "non" is pejorative, reinstantiating hierarchy of knowledge forms. Ultimately, informed awareness of pertinent literatures is also crucial, not, to echo Crease's account of physical sciences, "posturing and ideology" and "high-minded glorifications of 'boundary-crossing,' 'transgression,' and the production of 'new objects' (2017: 71, 85). Or, unsubstantiated proclamations of revolution and radical transformation in a postdisciplinary age when interdisciplinarity has become the new norm and cross-sector transdisciplinarity has displaced academic science. Or, romanticized images. A special issue of the journal *Nature* on interdisciplinarity depicted a visual metaphor of researchers as fantasy figures soaring through the air to "save the world" and scaling disciplinary walls (2015, p. 305). The scientific and societal challenges that confront us today, however, require more than characters styled after a Marvel comic book and calling interdisciplinarity "all the rage" (Ledford 2015: 308). Several contributors to the issue documented trends in funding, institutionalizing, and disseminating results. However a special issue alone, even in a prestigious journal, does not substitute for systematic incorporation of findings from authoritative accounts and attention to contexts.

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