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Interdisciplinarity and the Prospect of Complexity: The Tests of Theory

by
Julie Thompson Klein

Wayne State University
Interdisciplinary Studies Program

Abstract: William Newell's theory of interdisciplinary studies is a timely proposal since complexity is a keyword in contemporary descriptions of interdisciplinarity. Like any other theory, it is subject to a series of questions: (1) Is the theory generalizable, and is it reductive? (2) What relationship does it have to prior theories? (3) Does the theory drive practice, or vice versa? and (4) Is it fruitful? A weighing of these and related questions indicates that complex systems theory has heuristic value for conceptualizing interdisciplinary tasks and affirms crucial elements in the integrative process. However, the technical restrictions cannot account for all phenomena that constitute interdisciplinarity, and the relationship to other theories needs to be assessed.

WILLIAM NEWELL'S THEORY OF INTERDISCIPLINARY STUDIES is a timely proposal. Complexity is a keyword in contemporary discussions of interdisciplinarity, though the link was apparent in the earliest influential theories. In 1972, Erich Jantsch called for a new approach to education and innovation capable of fostering judgment in "complex and dynamically changing situations" (p. 102). Over time, complexity became a widely cited reason for interdisciplinary practice in a remarkable range of contexts, from literary studies, physics, and biology to education, public policy, and environmental studies. The starting point varied—the knowledge explosion, cultural diversity, social and technological problems, or multi-faceted concepts such as the "body," the "mind," or "life." The underlying premise was the same, though. The complexity of knowledge and society necessitates an interdisciplinary approach.

Newell's proposal would be welcome if for no other purpose than providing an explanation of complexity for those engaged in interdisciplinary work.

His proposal, though, goes well beyond basic explanation. Strong claims are made: conceptualization of the integrative process, stipulation of criteria for conducting and evaluating each integrative step, and a long awaited epistemological rationale for interdisciplinary studies.

In this response, I raise a number of tests of the adequacy of theory.

Theory and the Problem of Unity

The act of proposing a theory sets in motion a series of questions about its validity. Etymology furnishes a partial answer. The modern English word *theory* derives from the Latin *theoria,* which, in turn, derived from the Greek *theorein*. Its root meaning is looking at or viewing, contemplating or speculating. In general use, a theory connotes a scheme or system of ideas and statements, with associated rules or principles. At the most abstract level, a hypothesis may be unsupported, though in the sciences precise tests were developed to determine the validity of a theory within a particular domain of intellectual problems. Over time, scholars have called into question both classical traditions and empirical strictures and have developed a more sociological interest in how propositions operate within a community of knowers. Their critique of the assumption that any set of criteria captures all cases also undermined the belief that any theory could account for everything in a class of phenomena. These shifts have profound implications for any claim to unity.

Newell asserts that complex systems theory is capable of unifying the apparently divergent approaches to interdisciplinary studies. Yet, the assertion is suspect on two grounds. To begin with, as J. Linn Mackey also noted in his response, it is a modernist agenda in the midst of postmodern skepticism. In the case of interdisciplinarity, the premise of unity is all the more problematic because the class of phenomena is so immense and diverse. The first set of questions responds to both difficulties: Is the theory generalizable? And, is it reductive?

The first test—generalizability—asks whether a theory applies to a wide range of phenomena while offering a more systematic way of thinking about them and the underlying idea. The answer is a resounding "yes," as Newell's opening illustrations suggest. Acid rain, rapid population growth, and the legacy of *The Autobiography of Benjamin Franklin* can be productively understood as behaviors of complex systems, and they all require interdisciplinary study. He also posits other strong scenarios:

- interdisciplinary courses on phenomena modeled by complex systems may promote desirable liberal education outcomes for students

and corresponding faculty development;
- interdisciplinary study may prepare future professionals to confront the complex behaviors they will face on the job;
- the new knowledge produced by synthesizing insights from old knowledge about specific complex systems may free scholars to ask new questions about them;
- fundamental critiques may facilitate viewing society or politics or knowledge as the dynamic product of a complex of interacting systemic forces;
- partial reorganization of the university structure around different categories of complex systems may reduce the pressure for complete coverage of each discipline, eliminating an obstacle to downsizing.

These are tantalizing prospects. The second question, however, marks the limits of the theory's capacity. Any theory that demands fidelity to a particular explanation or method runs into trouble as an exercise in unity. There is a great difference between basing theory on technical detail and the license of metaphor. In the first instance, interdisciplinarity must now be understood in terms of a particular construction of complexity, from a field Newell himself acknowledges is a "technical morass" in flux (e.v.). System theorists, as Mackey also noted at greater length, disagree on terminology as well as theory. Any theory of interdisciplinarity constructed on a disputable claim within a contested discursive field is standing on a shaky foundation.

Ludwig Huber's description of interdisciplinarity—as a "jungle of phenomena"—also haunts the theorist (1992, p. 195).

The Jungle of Phenomena in the Garden

Newell acknowledges a diversity of activities: general and liberal education; professional training; social, economic, and technological problem solving; social, political, and epistemological critique; faculty development; financial exigency; and production of new knowledge. He even allows that motivations differ, but contends the consequences are the same. Any differences, we are told, reflect the varied consequences of studying complex systems, not mixed or conflicting types of interdisciplinarity. Systematicity and commensurability are severe tests of theory. Interdisciplinarity is a complex array of phenomena with ill-understood and unpredictable feedbacks to the knowledge system. Giles Gunn (1992) captured the problem of description best by writing that any effort to map interdisciplinary studies confronts "over-

lapping, underlayered, interlaced, crosshatched affiliations, coalitions, and alliances." He suggested that disciplines are undergoing change even as they are being used, and interdisciplinary interests are more akin to fractals than straight geometric lines, doubling, tripling, and even quadrupling (p. 249). Heisenberg is, then, the contemporary cartographer's guru, not Plato or Aristotle.

In rejecting the argument that "the very nature of interdisciplinarity varies from use to use," Newell also constructs a dichotomy of purists and a "vocal faction" that would "let a thousand flowers bloom" (p. 6). (The slogan, it should be noted, is an English version of a Chinese saying about letting all voices be heard without political censorship, a different connotation.) In the dichotomy, purists upholding "quality" and "conceptual clarity" stand guard against an eclectic group with no standards, herbalists who allow anything to propagate in their wild gardens (p. 6). Even those who resist conceptual closure, however, distinguish criteria of inclusion and exclusion. Their debates are sometimes heated, particularly on the question of what is "genuine" or "pure" interdisciplinarity. Furthermore, differences matter. They cannot be erased. The "instrumental" solution to an engineering problem is not of the same character and does not produce the same outcome as the production of "critical" feminist knowledge. Neither is fostering integrative habits of mind in general education the same kind of activity, with the same effect, as transferring concepts and methods across biology, chemistry, and physics in genetic research.

The plurality of phenomena is paralleled by an abundance of theoretical speculation.

Theorists in the Garden

Newell contends that no one has ever set out a comprehensive rationale for interdisciplinary studies. This news will come as a surprise to a number of people. As Stanley Bailis commented in his response, there is no lack of candidates. To be fully persuasive, any theory must also be tested in the forge of other theories, setting in motion another set of questions: What relationship does the new theory have to prior theory? Does it ignore, complement, enrich, or supplant previous efforts? What is the status of competing theorizations? Does prior theory provide a measure of how adequate the new theory is?

Interdisciplinary Theorizing

Theories have been put forward at several levels. To supplement Bailis's list of candidates—Auguste Comte, Hubert Spencer, the Vienna Circle, the Social Science Research Council, Thomas Kuhn, Alfred Kuhn, E. O. Wilson, and his own proposal in American Studies—I would add the epistemological writings of Jean Piaget (see 1972) and Joseph Kockelmans (1979). In the realm of humanities, Kenneth Burke's (1966) model of symbolic action and W. J. T. Mitchell's (1994) theory of the pictorial turn and typology of interdisciplinary forms stand out in a roster that would also include the work of Mieke Bal (1991) and Gene Wise (1978). Factoring in other fields, the list expands to include Brian Turner (1990) and Craig Calhoun (1991), among others. Moreover, interdisciplinarity has already been theorized on the ground of complexity. This body of work comprises an important comparative framework for weighing the strengths and weaknesses of any new theory. John Warfield (1994, 1995a, 1995b) has been tilling in this particular section of the garden for years, presenting numerous papers at annual meetings of the Association for Integrative Studies (AIS) and publications on related conceptual issues and the broad scope of applications. Others come to mind as well.

William Paulson (1991) situated the concepts of complexity and emergence within the generic problematics of categories of knowledge, discursive systems, and disciplinary matrices by which the totality of the universe is divided. Like Newell, Paulson makes a choice from the array of explanations, in his case accentuating information theory. The concept of self-organization from noise, Paulson suggests, provides a framework for understanding emergent qualities in many kinds of systems—inorganic, organic, and sociocultural. He concentrates on literary signification. Literary texts contain elements that are not immediately decodable and, therefore, function for readers as, what information theorists would call, "noise." What initially appears to be a perturbation in a given system turns out to be an intersection of a new system with the first one. Noise both within and outside the text can lead to the emergence of new levels of meaning that are neither predictable from linguistic and genre conventions nor subject to authorial mastery. In becoming aware of a new relation, readers create a new context in which a previously disruptive event or variety is reread.

The most extensive alignment of the two concepts lies in the work of Edgar Morin and Basarab Nicolescu. Knowledge of complexity, Morin urges, demands a politics of civilization. Achieving it will require reform of the university and the creation of a new dialogue that bridges humanistic and

scientific cultures. Nicolescu, who is a theoretical physicist, has proposed a model of transdisciplinarity supported by three pillars: complexity, multiple levels of reality, and the logic of the included middle. The logic of the included middle is capable of describing coherence among different levels of reality, inducing an open structure of unity that accords with the incompleteness theorem of mathematician Kurt Gödel. It is impossible to construct a complete theory for describing passage from one level of reality to another or the unity of levels. A sufficiently rich system of axioms inevitably leads to results that are either indecisive or contradictory, making the search for a complete understanding of a physical work or the more complex human sphere illusory. Transdisciplinary vision, Nicolescu argues, eliminates homogenization, replacing reduction with a new principle of relativity that emerges from the coexistence of complex plurality and open unity (For Nicolescu and Morin, see Nicolescu, 1994 ff. See also, Nicolescu, 1996).

Theory in the Realm of Application

Like Jack Meek, who moved in his response from Newell's intellectual orientation to social problems, I also call for testing theory in the realm of application. Modern societies are increasingly ruled by the unwanted side effects of their differentiated subsystems, such as the economy, politics, law, media, and science. These systems have developed their own running modes or "codes," to use Niklas Luhmann's term, that enable them to be highly productive (1997). Yet, differentiation produces imminent side effects in other fields that cannot be handled within the codes of the system. Indicative of this development, the problems of society are increasingly complex and interdependent. They are not isolated to particular sectors or disciplines, and they are not predictable. They are emergent phenomena with non-linear dynamics. Effects have positive and negative feedback to causes, uncertainties will continue to arise, and unexpected results will occur. "Reality" is a nexus of interrelated phenomena that are not reducible to a single dimension (Caetano, Curdao, and Jacquinet, 2000, p. 529; Egger and Jungmeier, 2000, pp. 301-302; Goorhuis, 2000, pp. 25-26).

Complexity is foundational to Gibbons' and Limoges' (1994) theorizing of changes in the way that scientific, social, and cultural knowledge are being produced today. In contrast to the older hierarchical and homogeneous method of knowledge production which they call Mode 1, and which emphasized disciplinary boundary work and certification, Mode 2 is characterized by complexity, hybridity, nonlinearity, reflexivity, heterogeneity, and transdisciplinarity. New configurations of research are being generated con-

tinuously, and the number of places where research is performed has increased. The Mode 2 process moves beyond older disciplinary structures and interdisciplinary practices to a synthetic reconfiguration and recontextualization of available knowledge. As expertise is drawn from a wider range of organizations, a new social distribution of knowledge occurs.

Mode 2 is labeled *trans*disciplinary because it is a *trans*gressive way of thinking about science. It does not respect disciplinary boundaries, and problems are not formulated in strictly scientific terminology. Multiple stakeholders are involved in formulating a problem from the beginning, bringing heterogeneous skills and expertise to the problem-solving process. As organizational boundaries of control blur, underlying notions of competence are also redefined and new criteria of evaluation are needed. Knowledge is not the "property" of a public or private customer. It maintains the "character" of public good, making the proper arena of judgment the *agora* of public debate. Wider contextualization and social distribution of knowledge, along with changes in the spatial and temporal structures of science, render the image of knowledge as a cognitive map with distinct territories and borders too static. Likewise, a tree with different branches is too linear. A wildly growing rhizome may be more appropriate. "Rhizome" is a word from botany, meaning a system of roots without a main root, without a center or hierarchy. Its order is not a structure of entities but connections (Nowotny, Gibbons, and Scott, 2001).

The "binomial relationship" of complexity and interdisciplinarity is also evident in the aerospace industry, one of many industrial and commercial contexts of complex systems thinking. The connection between complexity and cross-disciplinary structuring of knowledge is found in the interactions between incommensurate types of process or phenomena and the qualitative restructuring such interactions drive. Nonlinear interactions lead to symmetry breaking. The dimensions of description change, and there is a qualitative change in the variables and parameters relevant to understanding what is happening. Cross-disciplinary analysis introduces an investigative/exploratory element into analysis of decision issues, encouraging development of response options. The logic of "optimal" solutions is replaced by alternative criteria, such as the level of consensus that options attract, their feasibility, and contributions to the overall sustainability of a system (Jeffrey, Allen, et al. 2001, pp.182-184; Jeffrey, Allen, et al., 2000, p. 574).

Environmental problems also exemplify the link between interdisciplinarity and complexity. They comprise several sub-problems that fall into the domains of different disciplines and sectors. The concept of "biocomplexity"

that informs many current projects funded by the National Science Foundation is an interdisciplinary view of interactions within biological systems and with their physical environments. In studying the Florida Everglades, for instance, researchers are developing complex models of hydrological systems down to the level of individual animals in panther or deer populations. They are able to construct finely detailed maps that show how water releases will shape habitat quality for different species. Assembling this bigger picture takes tremendous computing and insights from ecology, mathematics, economics, and sociology. The result is a practical tool for policy makers (Colwell and Eisenstein, 2001). Restoring the Florida Everglades, however, will require more than interdisciplinary analysis. It will take transdisciplinary collaboration across sectors of society, introducing a further complexity.

There are wide variations in the preferences and values held by decision makers and stakeholders over qualitative, quantitative, and economic attributes of alternatives in a decision-making process (Nelson, 2000, p. 159; Sheringer, Jaeger, and Esfeld, 2000, p. 36). The integrative process of research in UNESCO's (United Nation's Educational, Scientific, and Cultural Organizations) biosphere reserves illustrates the bi-directional complexity of multiscalar and multi-sectoral problem solving. It is "horizontal" in the cooperation of disciplines at the same level during multi- and interdisciplinary research, in the involvement of different stakeholders in a local planning process, and in the cooperation of administrative bodies. It is "vertical" in the cooperation of disciplines at different levels, for instance, when scientific research is combined with best practices in a region, when NGOs (non-governmental organizations) and government agencies cooperate, and when local communities interact (Rhön and Whitelaw, 2000a, p. 426). Celine Loibl (2000) distinguishes three levels in dealing with complex systems and transformation processes. On the micro-level, research teams must learn to work in inter- and transdisciplinary settings that are inclusive of multiple stakeholders. On a meso-level, the science system is beginning to transform and to create appropriate curricula and institutional surroundings. On the macro-level, political transformations have had effects on the science system, Eastern Europe being a striking case in point.

The Art of Gardening

The greatest promise asserted for the new theory is finding the "Holy Grail" of integration. This quest leads to a further set of questions implied by the previous discussion of application: Does theory drive practice, does practice drive theory, or is the relationship reciprocal? Does theory improve practice?

Does observation of practice strengthen or weaken theory? A variety of process models have been proposed and descriptions of integrative approaches abound in reports on curriculum and research projects, albeit fragmentary and dispersed. Process models have the potential to improve practices by clarifying how integration occurs. However, they tend to be prescriptive and idealized.

The underlying premise of Newell's model is that complex systems theory specifies required steps for integration while conforming to some widely accepted principles for the conduct of interdisciplinary inquiry. Its rhetorical appeal is heightened by his suggestion that the current approach may not simply be "flawed" and "arbitrary," but worse, laden with "inappropriate" steps or even "fundamentally misguided" (p. 15). Newell distinguishes clustered steps focused on disciplinary perspectives and on integrating insights through construction of a comprehensive perspective or theme. The explanation is not accompanied at each step by a precise analogue in complexity theory, a point both Mackey and Bailis also made. Nonetheless, several valuable insights emerge.

Sorting Through the Steps

In the *Defining* stage, conceptualizing any task as a complex system can improve intellectual understanding from the outset, especially in realms of application where reflexivity does not have the same priority as it does in academic settings. In the *Determining* step, thinking in terms of how subsystems contribute to an overall pattern of behavior will facilitate a more comprehensive framework. The gap between the real and the ideal surfaces, however, in the exhortation for interdisciplinarians to "err on the side of inclusiveness (at least in their initial inquiries)" and "to be alert for nonlinear connections that may have escaped attention" (p. 17). These are laudable exhortations, but complexity reduction is a necessary commonplace, driven by pragmatics of time, personnel, material resources, and the demands of public and private agencies. Lack of time also plagues the *Developing* and *Gathering* steps.

Curiously, disciplinarians are left "off the hook." "Much of the new knowledge required by interdisciplinarians," we are also told, "is unlikely to ever be generated by the disciplines" (p. 18). Those connections "fall outside the purview of every discipline," making their exploration the responsibility of interdisciplinarians (p. 18). In an age when interdisciplinarity is becoming a common descriptor of research in many disciplines, and when reforms in higher education urge greater responsibility for connection-making within

major programs of study, integrative skills are becoming part of the toolkit of disciplinary preparation. This capacity is all the more important for the *Generating* step, when components and their relationships are to be clarified. If students do not know the connections between their disciplines and other fields, they can hardly be expected to generate them readily as workers and as citizens. In a different but related vein, Bailis also called attention to the existence of complexity within specialized disciplines.

The second cluster of steps begins with *Identifying* principles by which particular facets operate, probing the assumptions of disciplines that have utility for understanding those facets. Complex systems theory is tendered as the procedure for *Evaluating* through scrutiny and modification of the terminology used by contributing disciplines. *Resolving* and *Constructing* are also key steps, though it is not clear how the epistemology of complex systems theory informs a procedure already discussed in problem-focused research as "iteration." Calling it "oscillation" does not change the same process of working backwards from phenomena and forward from the sub-systems studied by different disciplines. In a different realm, Maurice deWachter (1982) grappled with the same issue in describing the difference between an ideal and a real model of bioethical decision making.

Modernist assumptions also linger in the interstices of the process model. Take the statement, "As it is, interdisciplinarians know what the pattern should look like." How do they know? Relatedly, if a theory rooted in complex systems theory assumes that some common ground solutions are "better than others," where does the assumption originate and are the solutions that follow generalizable (p. 21)? Furthermore, *Creating* common ground and *Producing* the more comprehensive understanding may not hinge on an intellectual understanding of how the behavioral pattern of the system comes about from its constituent parts, but rather on the political economy of status hierarchies that result in a greater surrender by some disciplinary participants than in others. No process is innocent of power. The messy realities of real world problem solving puts further stress on the description of how terminology and assumptions of contributing disciplines are adjusted: "The trick is to modify terms and assumptions as little as possible, while still creating adequate common ground on which to construct a coherent understanding" (p. 20). Complex systems theory stipulates the crucial step of identifying linkages between sub-systems. Yet, does it contain widely accepted criteria of adjudication?

I would add a final side note on the question of process. My preliminary attempt at describing stages in the process is used as a stepping-stone for the

model of process that accompanies this theory. Some time ago, I moved beyond this description. The context was an interdisciplinary model for research in town planning, policy, and decision making, prompted by criticism of the underlying linearity of the descriptive steps by practitioners. The new model is a socio-linguistic conceptualization of managing complex problems. Skills, steps, and principles are clustered in a bi-directional scheme that moves across horizontal and vertical planes. A functional balance between differentiation and unification emerges in the midst of two tradeoffs: between all knowledge that might be utilized and what is actually used and between the power of disciplinary inputs and the rigor with which interdisciplinary salient concepts or global questions are utilized to create a common framework. The earlier descriptive steps reappear, but they are extended and recontextualized in an iterative model of communicative action in the dynamics of data, information, knowledge, intuition and insight, judgment, retrospection, and decision making. In a subsequent proposal for a generic model of integrative process, I retained the fundamental dialogical coexistence of differentiation and unity (Klein, 1996, pp. 222-224; 1990-1991).

Theory or Metaphor?

In its etymological origin, the word "theory" suggests not only abstraction, but empirical grounding. Someone who theorizes is observing some reality closely, considering and speculating on its nature in order to arrive at a generalizable statement about how it works. To demand that complexity become the ground zero of interdisciplinarity—its "necessary and sufficient condition" (e.v.)—and to locate necessity in "the structure and behavior of complex systems" (p. 1) asks more of the theory than it can deliver. Its technical restrictions do not account for all of the phenomena associated with interdisciplinarity, and any exercise in theory must weigh competing prospects.

A final test awaits, embodied in three related questions: Is the theory fruitful? Does it enhance understanding of the idea of interdisciplinarity? Will it stimulate new work? Take humanities, billed by Newell as a hard case. Studying complex systems does indeed tend to resonate better with natural and social scientists than members of humanities and the arts, who have traditionally resisted explanations of behavior and creativity in the scientific vocabulary of law, predictability, and regularity. They have also demonstrated a greater interest in behavior that is idiosyncratic, unique, and personal. This characterization is becoming increasingly less true, however, in the zones of interaction between humanities and social sciences where dichotomies of

influence/response and cause/effect are being dismantled. Many humanists today talk of motives, authority, persuasion, exchange, and hierarchy.

Newell calls attention, quite perceptively, to the role of "contextualization" in the contemporary humanities (see p. 4). One of the effects of heightened historical and sociological understanding of how ideas, events, texts, and artistic productions circulate has been to render culture a complex system with ill-understood feedbacks between individual/local expressions with larger systems. This development, though, leads to the last question, the one Meek put on the table. Must complexity be self-conscious in interdisciplinary work? Meek's answer was "no," though he encouraged using its elements to facilitate a more collective, participatory, engaging, and inclusive decision-making process. My answer is "yes" and "no."

All interdisciplinary work will be improved by more self-conscious focus on the process of integration. In that conviction, I wholeheartedly join Newell. The project of complexity, though, is already well underway in humanities, not in the name of complexity but the problematics of universality, objectivity, and mono-disciplinary solipsism. In the end, that is the "acid test." The proposed theory may well stimulate new work, passing the test of fruitfulness. Yet, the number of people who regard complex systems theory as the "appropriate," indeed "legitimate," focus for interdisciplinarity will be far smaller than the number of people who find it to be a useful metaphor. Others will share Bailis's interest in patterns that may lack the stipulations of complexity; in agreements rather than conflicts in elements of different disciplines; and in topics, problems, or themes that are pursued without self-conscious reflection on their disciplinary makeup.

The likelihood of wide adoption is also compromised in the puzzle over "fear of exclusion" (p. 3). If the new theory becomes accepted, Newell asked, would people be drummed out of "the interdisciplinary studies profession" if they did not embrace it, or, a lesser complication, would they be forced to justify themselves every time they adopt an interdisciplinary approach to study a new problem? His answers, respectively, were "highly unlikely" and "yes" (p. 3). Both questions beg the same assumption. Who constitutes "the profession?" The number of people who identify as members of a group that attempts to control the broad field of phenomena and associated concepts and methods that the word "interdisciplinarity" connotes—a classic definition of a "profession"—is significantly smaller than the number of people who engage in interdisciplinary work. Within AIS, laudable projects have emerged from efforts to "professionalize" interdisciplinary studies, and William Newell has provided unparalleled leadership in this effort. Yet, other

groups claim province over, and advance particular, interdisciplinary domains. Comparably, Bailis casts strong doubt on whether consensus ever occurred, highlighting distinct sets of problems in different domains of interdisciplinarity that undermine the premise of paradigmatic claims.

In the end, hearkening back to the tests of theory, do we have before us an accurate explanation of a phenomenon, a field, or a body of knowledge? Newell furnishes a powerful metaphor for improving conceptualization and practice. His stipulations for process—especially greater reflexivity and taking time to acquire requisite disciplinary knowledge—should be heeded in all quarters. Theory, though, entails a more comprehensive and tougher set of tests.

Biographical note: Julie Thompson Klein is Professor of Humanities in the Interdisciplinary Studies Program at Wayne State University. She consults widely on interdisciplinary research and education. Her books include *Interdisciplinarity: History, Theory and Practice* (1990) and *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities* (1996); the co-edited volumes *Interdisciplinary Studies Today* (1994) and *Transdisciplinarity: Joint Problem Solving among Science, Technology and Society* (2000); and the AACU monograph*, Mapping Interdisciplinary Studies Today* (1999).

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