

Interdisciplinarity and complexity: An evolving relationship*

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Abstract

In recent decades, the ideas of interdisciplinarity and complexity have become increasingly entwined. This convergence invites an exploration of the links and their implications. The implications span the nature of knowledge, the structure of the university, the character of problem solving, the dialogue between science and humanities, and the theoretical relationship of the two underlying ideas.

Introduction

Both interdisciplinarity and complexity are modern ideas. However, the underlying concepts of interdisciplinarity – breadth and general knowledge, integration, and synthesis – are ancient. Organized programs date to the opening decades of the twentieth century, in social science research and the core curriculum and general education movements. Precedents for the idea of complexity are traced to the early twentieth century, in disciplines such as biology and philosophy. The new science of complexity, though, developed in the latter half of the century. In recent decades, the two ideas have become increasingly entwined.

The link between the two ideas was evident in the earliest major theories about interdisciplinarity. At the first international conference on interdisciplinary research and higher education, Erich Jantsch called for a new approach capable of fostering judgment in “complex and dynamically changing situations” (1972: 102). Indicative of the era, the organizing languages of Jantsch’s model of the system of education and innovation were logic, cybernetics, planning, general systems theory, and organizational theory. A decade later, S. Smirnov (1984) identified “system-complex interdisciplinarity” as one of the main ontological forms of interdisciplinary development in modern science. Smirnov believed the discovery of systems-forming and system-organizing links and regularities among distinct diverse departments, parts, and elements held the promise of elaborating a common theoretical structure (1984: 71-72).

As the new science of complexity developed, complexity also became a keyword in discussions of interdisciplinarity. In their paper “Advancing interdisciplinary studies,” Klein and Newell (1997) defined inter-disciplinary study as “a process of answering a question, solving a problem, or addressing a topic that is too broad or complex to be dealt with adequately by a single discipline or profession.” In a study of overlapping thought in subjects, Ursula Hübenthal (1994) explained that interdisciplinary collaboration is required because “problems are much too complex to be judged appropriately, much less solved, merely with the subject-knowledge of a single discipline.” In commenting on prospects for social sciences, Marilyn Stember (1991) exhorted participants in interdisciplinary efforts to “have an eye toward the holistic complex of interrelationships.” Regarding the inherent complexity of health care issues, Bryan Turner (1990) asserted that “Given the complexity of health issues, the approach of medical and sciences *ought* to be interdisciplinary.” And, in a discussion of multicultural curriculum reform, Grant Cornwell and Eve Stoddard (1994) declared that “Cultures, in their ever-shifting interactions and complexities, need to be both researched and taught from interdisciplinary perspectives” (after Newell in *Issues in Integrative Studies*, 2001).

Complexity is no less plural than interdisciplinarity. The idea is wide ranging and the boundaries of definition fluid. Systems theorists have differing commitments to dynamical systems theory, nonlinear dynamics, systems dynamics, and complex dynamics. Complexity and interdisciplinarity are linked in a wide range of practices, from literary studies, physics, and biology to education, public policy, and environmental studies. The starting point varies – the knowledge explosion, cultural diversity, social and technological problems, or multifaceted concepts such as the body, the mind, or life. The pairings of these two ideas have powerful implications for the most basic notions at stake in this congress – the nature of knowledge, the structure of the university, the character of problem solving, the dialogue between science and humanities, and the theoretical relationship of complexity and interdisciplinarity.

Rethinking knowledge

The complexity of knowledge is suggested by the current rhetoric of description. Once described as a *foundation* or *linear structure*, knowledge today is depicted as a *network* or a *web* with multiple nodes of connection, and a *dynamic system*. The metaphor of unity, with its accompanying values of universality and certainty, has been replaced by metaphors of *plurality* *relationality* in a *complex* world. Images of *boundary crossing* and *cross-fertilization* are superseding images of disciplinary *depth* and *compartmentalization*. Isolated modes of work are being supplanted by *affiliations*, *coalitions*, and *alliances*. And, older

values of *control*, *mastery*, and *expertise* are being reformulated as *dialogue*, *interaction*, and *negotiation*. Changes in the spatial and temporal structures of knowledge also call into question traditional images of knowledge as a cognitive *map* with distinct *territories and borders* or a *tree with different branches*. They are too linear. In their place, images of *fractals*, a *kaleidoscope*, or a wildly growing *rhizome* without a central root have been proposed (Klein, 1999).

The quantitative picture of knowledge is another indication. By the year 1987, there were 8,530 definable fields. By 1990, roughly 8,000 research topics in science alone were being sustained by specialized networks, and as many as 4,000 disciplines have been identified as the result of accelerating differentiation of the science system. Historical separations of disciplines are still inherent in the way that universities function, but they are eroding and even becoming obsolete in some areas. The inner development of the sciences has posed ever broader tasks leading to interconnections among natural, social, and technical sciences. The same object – an organism – is simultaneously a physical (atomic), chemical (molecular), biological (macromolecular), physiological, mental, social, and cultural object. As mutual relations are reconsidered, new aggregate levels of organization are revealed and ‘multidisciplinary’ is becoming a common descriptor of research objects (Crane & Small, 1991: 197; Clark, 1995: 193; Habib, 1990: 6). The emergence of interdisciplinary fields is another key factor. Since 1945, a significant number of fields with a multi- or interdisciplinary character have evolved, many from cross-fertilizations of hierarchically unrelated fields, new mission-oriented fields and subject fields. Examples range from area studies, women’s studies, environmental studies, urban studies, and cultural studies to social psychology, policy sciences, criminology, and gerontology to cognitive sciences and information sciences, materials science, and molecular biology.

Disciplinary change is a compounding factor. The discovery of DNA in the 1970s was a veritable ‘cognitive revolution’ that refigured traditional demarcations of physics, chemistry, and biology. New fields of application also arose, creating new markets for genetic technologies while raising critical questions about the status of biology in society. In the geosciences, new discoveries, tools, and approaches changed the way that research is conducted at empirical and methodological levels. The theory of plate tectonics fostered new linkages among the disciplines of earth science and, in certain fields of geoscience, strategic analysis capable of identifying ‘real-world’, user-oriented problems and demands is called for (Neumann-Held & Rehmann-Sutter, 2000; Haribabu, 2000; Schönlaub, 2000). Humanities have been affected as well. The movement known as ‘theory’ stimulated new historical-cultural studies of the discursive practices of objects, such as the body, the family, race, and the medical gaze. Such changes are difficult to map. In making the attempt in literary studies, Giles Gunn (1992) highlighted “overlapping, underlayered, interlaced, crosshatched affiliations, coalitions, and alliances.” The threading of disciplinary principles and procedures is frequently “doubled, tripled, and quadrupled in ways that are not only mixed but, from a conventional disciplinary perspective, somewhat off center” (1992: 248-49). Interdisciplinary activities interconnect in a shifting matrix with unpredictable synergistic relationships.

A significant number of new specialties also have a hybrid character. They constitute a second form of specialization focused on areas missed or only partially examined by traditional disciplinary specialties. Examples range from astrophysics and artificial intelligence to medical anthropology and child development. Hybrids also beget other hybrids, especially in the natural sciences, where higher degrees of fragmentation and hybridization occur. Neuro-endocrinology, an alliance within physiology between endocrinology and neurophysiology is a second-generation hybrid. Dogan and Pahre (1990) view hybridization as a general characteristic of knowledge production today. As innovative scholars move from the core to margins of their disciplines, specialties are recombined continuously, with two results:

1. formally institutionalized subfields of one or another formal discipline or permanent committees or programs that regularize exchanges;
2. informal hybridized topics, such as development, that may never become institutionalized fields.

The “jungle of phenomena” associated with interdisciplinarity, to borrow Ludwig Huber’s (1992: 195) phrase, has implications for how we think about the place where knowledge is represented – the university.

Rethinking problem solving

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 (1997), that enable them to be highly productive. However, 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 nonlinear dynamics. Effects have positive and negative feedback to causes, uncertainties continue to arise, and unexpected results occur. ‘Reality’ is a nexus of interrelated phenomena that are not reducible to a single dimension (Goorhuis, 2000; Egger & Jungmeier, 2000; Caetano, *et al.*, 2000).

The need for a new approach to complex problems is evident across fields of human interaction with natural systems (e.g.,

agriculture, forestry, industry, megacities) and in fields of major technical development (e.g., nuclear technology, biotechnology, genetics). Social, technical, and economic developments also interact with elements of value and culture in aging, energy, health care, and nutrition. Interdisciplinarity is often endorsed as a solution, but earlier approaches differ from new transdisciplinary approaches. The history of interdisciplinary problem-focused research dates from the 1940s, initially in agriculture and defense-related research. In the 1970s, industrialized nations began allotting increased funding for multi- and interdisciplinary research in areas of economic competition, especially engineering and manufacturing, computers, biotechnology, and medicine (Klein, 1996: 173-208). The necessity of an interdisciplinary approach when dealing with complex systems was also being recognized, but the desirability of 'progress' and 'growth' was taken for granted (Pivot, 2000).

At the same time, a new discourse of transdisciplinary problem solving was emerging. The new discourse bridges the historical gap between calls for interdisciplinarity and problem orientation, on the one hand, and a disciplinary, practical policy of support for natural sciences and technology, on the other hand (Jahn, 2000). It was evident during the late 1980s in Swiss and German contexts of environmental research. Like interdisciplinarity, 'transdisciplinarity' has more than one meaning. The most widely recognized definition at that point was a comprehensive framework for reorganizing the structure of knowledge. General systems, structuralism, Marxism, evolution-sociobiology, phenomenology, and feminism are leading examples. The new discourse centers on problem- and solution-oriented research incorporating participatory approaches. In reviewing the German-language literature, Christian Pohl (2000) identified five keywords: *problem-oriented*, *beyond disciplinarity*, *practice-oriented*, *participatory*, and *process-oriented*. The problems to be solved do not originate with science. They are external developments in *Lebenswelt*, the living world. There is, moreover, a growing number of problems 'without a discipline'.

The new discourse shares several important assumptions with Funtowicz and Ravetz's (1991) notion of "postnormal science": it breaks free of (1) reductionist and mechanistic assumptions about the ways things are related and systems operate, (2) normative social values uninformed by stakeholder and community inputs, and (3) the expectation that science delivers final, precise estimates with certainty. Likewise, postnormal science is associated with 'unstructured' problems that are driven by complex cause-effect relationships. They exhibit a high divergence of values and factual knowledge in a context of intense political pressure. Hence, the stakes in decision-making are high, and epistemological and ethical dimensions are marked by uncertainties (van de Kerkhof & Hisschemöller, 2000; Klabbers, 2000; Nentwich & Bütschi, 2001; Truffer, *et al.*, 2001). These conditions are evident across problem domains.

Problem domains

Many of the problems professionals face are neither predictable nor simple. They are unique and complex. Arising from environments characterized by turbulence and uncertainty, complex problems are typically value-laden, open-ended, multidimensional, ambiguous, and unstable. Labelled 'wicked' and 'messy', they resist being tamed, bounded, or managed by classical problem-solving approaches. As a result, the art of being a professional is becoming the art of managing complexity. There are more tools than ever. Sophisticated analytical methods and computer software make it possible to handle increasingly greater amounts of information, facilitating large-scale modeling and forecasting. Deeper scientific knowledge and technical expertise also continue to emerge from the disciplines. However, complex problems cannot be solved by simply applying new information and tools or adding more variables to existing decision models and computer programs. Complex problems are not in the book but in the "indeterminate zones of practice" and the "swamp of important problems and nonrigorous inquiry." Furthermore, they are not solved once and forever. They must be continuously managed (For a summary of this literature and an interdisciplinary model for design, planning, and policy making, see Klein, 1990-91).

The aerospace industry is one of many industrial and commercial contexts of complex systems thinking. The "binomial relationship" of complexity and cross-disciplinary structuring of knowledge, Jeffrey, *et al.* (2000) found, lies in 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, *et al.*, 2000; Caetano, *et al.*, 2000).

Application is not the only realm where complexity and new forms of interdisciplinarity meet. At a colloquium on transdisciplinarity held at Royaumont Abbey in France, Katherine Young (2000) described research that integrates world religions, women's studies, and cross-cultural anthropology. Its interdisciplinary character lies in continuous comparison across three sets of analysis: among types of small-scale societies, among large-scale societies, and between the two groups. More finely-tuned comparisons emerged that are historically and socially nuanced, producing interdisciplinary patterns or generalizations that are determined inductively. Variables are then tested for necessity to the pattern. The transdisciplinary character of research was evident in studies of women and religion for projects related to social issues of policy or law, such as euthanasia, homosexuality, and male violence. Three traits made one particular project transdisciplinary. It was *mega* in size, focusing on men's roles and realities across time and cultures. It was *complex*, addressing distinctions of gender in the organization of cultures. And, it was *elusive*, grappling with difficult issues that had not been fully explored before (in Somerville & Rapport, 2000).

Environmental problems exemplify the new relationship of interdisciplinarity and complexity. Environmental problems comprise several subproblems that fall into the domains of different disciplines and social sectors, introducing a further level of complexity. There are wide variations in the preferences and values of decision-makers and stakeholders over qualitative, quantitative, and economic attributes of alternatives in a decision-making process (Nelson, 2000; Scheringer, *et al.*, 2000). The integrative process of research in UNESCO's biosphere reserves illustrates the bidirectional complexity of multi-scalar and multi-sectoral research on environmental problems. 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 example when scientific research is combined with best practices in a region, NGOs and government agencies cooperate, and local communities interact (Rhön & Whitelaw, 2000).

New vision-enhancing tools of information technology and nanotechnology are enhancing the relationship of interdisciplinarity and complexity. They are capable of revealing common principles underlying both physical and biological sciences. The same principle of fractal branching is at work in the form of a river network, the veins of a leaf, and the propagation of cracks in materials that are fatigued. At an international conference on transdisciplinary problem solving held in Zurich, Robert Eisenstein of the U.S. National Science Foundation described a shift in scientific research from the metaphor of a microscope to a *kaleidoscope*. The microscope has been the dominant image of research, manifested in the reductive approach of taking things apart into their separate components. It was, and continues to be, a highly successful source of knowledge. A new metaphor, though, is apparent – the kaleidoscope. Turning the tube of this popular child's toy creates shifting shapes and colors, resulting in new and unpredictable patterns and hues.

The concept of 'biocomplexity' is an interdisciplinary view of interactions within biological systems and with their physical environments. Complexity is evident in the shape of a spiral at all scales, from a hurricane taking shape on earth to a galaxy that is 100,000 light years across to gravitational waves across the largest scales of the universe. Computers can generate three-dimensional models of everything from a human heart to a landscape, envisioning the heart's electrical activity and, with terascale computing, facilitating faster prediction of storms on a finer scale. Even nanostructures can be viewed at the level of red blood cells and microelectronic mechanical systems.

The Florida Everglades illustrates the concept of biocomplexity in action. To restore the Everglades, we need to know how different hydrologic schemes will affect key species. Researchers can develop 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 would shape habitat quality for different species. Assembling this larger picture takes tremendous computing power, plus insights from ecology, mathematics, economics, and society. The result is a practical tool for policymakers (Colwell & Eisenstein, 2001). Actually restoring the Florida Everglades to ecological health, however, will require more than interdisciplinary tools.

From interdisciplinary to transdisciplinary problem solving: North and South

The difference between older, linear approaches to problem solving that combined existing disciplinary approaches and new transdisciplinary research is illustrated by the paradigm shift of sustainability. The concept of sustainability challenged the dominant Western paradigm of social transformation, embodied in older interdisciplinary concepts of modernization and development. It moved beyond narrow indicators of economic efficiency to include social justice and political regulation. In industrialized countries, the participatory turn in technology assessment and public interest in 'co-management' and 'decentralization' of renewal resources and environments fostered new approaches in areas as diverse as urban revitalization and rural farming. The gap between North and South was also addressed. In the past, interactions between North and South have tended to be one-way applications of knowledge delivered by a 'first-civilization' to a 'second civilization'. They were not appropriate to local social, cultural, economic, and ecological realities. They also discounted indigenous knowledge and accessible forms of traditional technology. An imbalance continues, but new models of knowledge production and technology generation have emerged (Mey, 2001). In describing a project on technology adoption in India, Hiremath and Raju (2000) emphasized that farmers did not use the socioeconomic variables of researchers. Scientists' and farmers' perceptions are shaped by their respective aims. Indigenous Gandhian concepts of Swadeshi, Trusteeship, and the cultural model of a Nine-

Square Mandala provided a more appropriate holistic view. The Mandala is a heuristic that recognizes both outer-material and inner-non material spheres of individual and family understandings of livelihood 'security' (Fry & Jurt, 2000; Hiremath & Raju, 2000).

A project in Ethiopia illustrates what a transdisciplinary approach to a complex environmental problem requires. In the highlands of East Africa, the rural population is caught in a cycle of underdevelopment and environmental degradation. Population pressure has pushed cultivation and livestock grazing to steep slopes and fragile lands, causing serious devegetation and soil erosion. At the same time, about 12 million ha of Vertisols (heavy though fertile soil) remain underutilized because of poor internal drainage and consequent flooding and waterlogging during the rainy season. In designing an approach to the problem, researchers considered indigenous knowledge and farmers' preferences. Farmers were even involved in testing component disciplinary technologies at the levels of plot, animal, and farm. Yet, they often did so separately, and assessment of impact was done primarily in bio-economic terms, maximizing criteria of yield and income. Over the course of the project, the need for simultaneous assessment of economic, social, and environmental effects of technology interventions became apparent. If ways of improving ecosystems and human welfare are to be identified, interrelationships between biophysical and human dimensions must be integrated spatially and temporally. Human, policy, and technical dimensions must be integrated at the levels of plot, household, and watershed or community. A holistic framework using the agroecosystem health approach is needed (Jabbar, 2000).

Several lessons follow from this discussion. First, in a complex problem domain, the research field is open and ill-defined, and the reality being investigated consists of a nexus of phenomena that are not reducible to a single dimension. Their meaning is context dependent, and the relationship between elements under study constitutes a core concept for complexity (Caetano, *et al.*, 2000). Second, common ground and a more comprehensive, holistic understanding do not derive from an idealized model of how the behavioral pattern of the system comes about from its constituent parts. They emerge in the cross-fertilization of multiple methods and perspectives that are adapted to the task at hand. Third, research is multilevel. 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 effects on the science system (Loibl, 2000). An added lesson is that new forms of knowledge, institutional structure, and problem solving require a new dialogue of science and humanities.

Sustainability is a major testing ground for integrating science with both humanities and social sciences. Traditionally, natural sciences have dominated environmental research. Social science approaches have not been incorporated into the mainstream of environmental research, and environmental considerations are still excluded from the mainstream of social science. UNESCO's MOST program (Management of Social Transformations) aimed to bridge the natural and social sciences. The project on "Sustainability as a Concept for the Social Sciences" was designed and organized by the Frankfurt Institute for Social-Ecological Research. Scholars from different branches of social sciences and varied regional and cultural backgrounds collaborated. In outlining an analytical framework for cross-disciplinary sustainability research, the group called for greater understanding of normative issues such as international justice between North and South, social justice within societies, equity in gender relations, and democratic participation in decision-making processes. Strategies are also needed to enhance the ability of key social actors to move towards more sustainable practices through transformations that incorporate knowledge about the behavior of strongly-coupled social and ecological systems. Scientific efforts are embedded in a dynamic, self-referential process of solving social and ecological problems on different scales of space and time (Becker, *et al.*, 1997; Becker & Jahn, 1999).

The traditional humanities have other roles to play. The discipline of philosophy, for instance, has always been concerned with fundamental assumptions and values of human inquiry and relationships among knowledge forms. New problems of justice and fairness and ethics in professional practice have prompted calls for renewal of the traditional branch of ethics and the capacity for reflexivity across all disciplines, fields, and social sectors. At the Royaumont colloquium on transdisciplinarity, Sheldon Krinsky described the applied role of epistemology in a project on ecological effects of genetically-engineered crops. Krinsky (2000) evaluated evidentiary support for scientific claims about the risk of using new transgenic crops. Regulators use claims to justify approval of field-test proposals. Epistemic analysis of underlying assumptions produced a more complex matrix of evidentiary categories that could be used by the project member charged with reviewing environmental assessments of the United States Department of Agriculture (in Somerville & Rapport, 2000),

Language, one of the most ancient members of the family of humanities, is also crucial. Languages of concordance exist, prominent among them general systems, mathematics, and computers. They cannot simply be applied, however. Emergence is one of the core properties of interlanguage. At the Zurich conference on transdisciplinarity, Thomas Bearth (2000) described the challenge of achieving “communicative sustainability” in the complex multilingual context of Africa. Researchers must be aware of not only scientific and technical languages but also the ‘unofficial’ languages and discourses of stakeholders in such vital problem contexts as health (e.g., AIDS), ecology (e.g., bush fires), and agricultural diversification and democratization. In both North and South, the language of target groups has not been viewed traditionally as a resource for solving problems. Reporting on a project on the future imaging of cultural landscapes in Austria, Lukesch, *et al.* (2000) stressed the importance of linking scientific and everyday language. Project organizers had to bridge the differing languages of a scientific team; local actors in development and decision making; the local population of consumers, workers and residents; and the broad public represented by mass media.

Calls for transdisciplinarity, Upendra Baxi (2000) emphasized at Royaumont, arrived at a moment of wider crisis in the discourse of human rights accountability. New modes of knowledge, discourse, and institutional frameworks are needed across all sectors of academic, private, and public life. Gaps between Western and non-Western traditions must be bridged, as well as esoteric and organic knowledges, colonial and indigenous traditions, official and people’s knowledges. One of the transgressive purposes of the new discourse of transdisciplinarity is to renounce the logic of instrumental reason by creating a more democratic discourse involving participation (Baxi, 2000). Both science and humanities are resituated within a broader context of social responsibility that is more than 5%, the allotment for the Ethical, Legal, and Social Implications program in genome research. Nothing less than Edgar Morin’s (1997) vision of a politics of civilization will do, a vision that requires reform of the university and creation of a new dialogue that bridges humanistic and scientific cultures.

Conclusion: Theorizing interdisciplinarity and complexity

The relationship between interdisciplinary studies and complexity was the explicit subject of a recent debate in the U.S. William Newell proposed that interdisciplinarity is necessitated by complexity. The nature of complex systems, he adds, provides a comprehensive rationale for interdisciplinary study, unifies the apparently divergent approaches, and offers guidance for criteria in each step of the integrative process. The ultimate objective of any interdisciplinary inquiry becomes understanding the portion of the world modeled by a particular complex system. Invited respondents answered the proposal on several grounds. Stanley Bailis pointed to other rationale and guides for integration, disputed the premise that there is consensus on definition, and contended that interdisciplinarity is warranted when complexity is absent. Jack Meek moved beyond Newell’s abstract focus, using the example of the Institute for Community Leadership to show that the exact formulation of integrative process does not have to be applied consciously. However, Meek added, the presence of its elements will facilitate more collective, participatory, engaging, and inclusive decision-making. J. Lynn Mackey questioned the notion that an integrated, complex system theory exists and called attention to mixed details from the Santiago theory of autopoiesis, dynamical systems theory, and the Gaia theory, plus conflation of the notions of complex ‘behavior’ and ‘system’. Joining the respondents, I acknowledged the heuristic value of the theory but also disputed the premise of consensus, cited competing theorizations, and argued that the technical restrictions of the proposed theory cannot account for all phenomena that constitute interdisciplinarity. Like Mackey, I also noted that each step in the integrative process does not have an analog in complex systems theory and that the attempt to construct a universal theory of interdisciplinary studies is a modernist agenda which is at bottom reductive. (*See Issues in Integrative Studies*, 2001).

The convergence of interdisciplinarity and complexity is ultimately part of a larger cultural process. Older epistemological classifications and domains of expertise have become more permeable, and widespread crossing of national, political, and cultural boundaries has occurred. Along with information technologies, international transport of goods and people, new networks, and cultural particularities, these developments have been lumped under the umbrella term ‘postmodernism’. A central feature of postmodernism is reversal of the differentiating, classificatory dynamic of modernity and increasing hybridization of cultural categories, identities, and previous certainties. New forms of interdependence and cooperation call attention to a worldwide reconfiguration. All cultural categories, identities, and certainties have undergone de-differentiation, de-insulation, and hybridization. All boundaries are at risk (Muller & Taylor, 1995: 258).

Contests of legitimacy over jurisdiction, systems of demarcation, and regulative and sanctioning mechanisms continue, and perceptions of academic reality are still shaped by older forms and images. Yet, boundaries are characterized by ongoing tensions of permanency and passage. Simplified views of the complex university only add to the problem of operational realities that outrun old expectations, especially older definitions that depict one part or function of the university as its “essence” or “essential mission” (Clark 1995, 154). Repeating the same metaphors, Harvey Goldman (1995) cautions, adds to the confusion, impeding understanding of new knowledge, new relationships, and nonlinear, non-vertical perspectives that are multidimensional and multidirectional. A wider range of physical and topological or architectural metaphors are being used to describe relations of elements that make up innovations and their contexts – dimensions, joints, manifolds, points of connection, boundedness, overlaps, interconnections, interpenetrations, breaks, cracks, and handles (1995, 222-23). And ... we might add ... a Mandelbrot set.

Notes

* A shorter, edited English-language excerpt of a Spanish-language chapter based on an address delivered at an international congress on "Interdisciplinary Studies and Complexity" at the UNAM in Mexico City; with permission of the editors of *Estudios Interdisciplinarios y Complejidad*. Ed. SigloXXI-CEIICH, UNAM, México. 2004. ISBN: 970-32-0864-9.

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