Interdisciplinary Needs: The Current Context

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ABSTRACT

MEETING THE INTERDISCIPLINARY NEEDS of today's library users begins with understanding the activities that create these needs. The answers to three basic questions provide the basis for a common discourse about those activities and their place in the knowledge system: (1) why and how do interdisciplinary activities emerge? (2) what form do they take? and (3) where are they located in institutions? Interdisciplinary activities are the result of historical and contemporary developments in disciplines, professions, and new interdisciplinary fields. Recent accounts indicate that interdisciplinarity is no longer peripheral to the academy but is regarded in many quarters as essential to the knowledge system. The cumulative effect of alternative organizations of knowledge and new social and cognitive forms exposes a lack of fit between interdisciplinary needs and existing knowledge taxonomies and classification schemes.

INTRODUCTION

Meeting the interdisciplinary needs of today's library users begins with understanding the activities that create them and their place in the knowledge system. The task of understanding is complicated by the "jungle of phenomena." Interdisciplinarity, as Ludwig Huber put it, is on "everyone's agenda" (Huber, 1992a, 1992b, p. 285). Borrowed tools and methods stimulate cross-fertilization. New concepts and theories transform the ways that objects are treated in traditional disciplines. New subjects generate interlanguages and hybrid knowledge communities. The challenges of the modern world require integrative problem solving and,

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at a more comprehensive level, holistic thought and transdisciplinary schema promote unity of knowledge.

The information needs created by these activities land squarely on the desk of the librarian, whose job it is to organize knowledge and make it accessible. Yet, Susan Searing (1992) remarked earlier, interdisciplinary approaches call into question the familiar verbal, numerical, and spatial systems on which we rely. Classification systems function as a "hegemonic representation of human knowledge." Interdisciplinary studies and many modern subjects "must be squeezed into pre-existing outlays of knowledge that no longer fit the shape of current scholarly output" (pp. 9-10).

The problem of interdisciplinarity is the problem of fit. The metaphor of fit, Lynton Caldwell (1983) observed in a genealogy of environmental studies, prejudges the epistemological problem at stake. Interdisciplinary approaches arise because of a perceived misfit among needs, experience, information, and the structure of knowledge embodied in conventional disciplinary organization. They represent a "latent and fundamental restructuring of knowledge and formal education" (p. 247). Recent accounts of interdisciplinary activity affirm Caldwell's claims. They indicate that interdisciplinarity is no longer peripheral to the academy. In many quarters, it is regarded as essential to the knowledge system (Salter & Hearn, 1993; Klein, in press; Klein & Newell, 1996).

The current extent of interdisciplinary activity and the attendant rise of alternative organizations of knowledge underscore the need for a common discourse about interdisciplinary needs. The answers to three basic questions provide the basis for such a discourse. Why and how do interdisciplinary activities emerge? What form do they take? And where are they located in institutions?

Interdisciplinary Activities

Klein and Newell grappled with the first question—Why and how do activities emerge?— when they wrote the chapter on "Interdisciplinary Studies" for the new edition of the *Handbook on the Undergraduate Curriculum.* They found familiar reasons alongside new ones:

- general education, liberal studies, and professional training;
- social, economic, and technological problem solving;
- social, political, and epistemological critique;
- holistic systems and transdisciplinary approaches;
- cross-fertilizations of borrowing and subdisciplinary interactions;
- new fields, hybrid communities, and inter-institutional alliances;
- faculty development and institutional downsizing. (in press)

The intermingling of older and newer reasons is not surprising. "Interdisciplinarity," Geoffrey Squires (1992) reflected recently, "is both a permanent and a transient issue in higher education" (p. 201). Any restructuring of knowledge creates the possibility of questioning, altering,

or transcending those structures. Yet interests come and go as a result of factors internal and external to the higher education system (p. 201). Consequently, current activities exhibit both historical and contemporary influences (for histories, see Kockelmans, 1979; Klein, 1990).

In the West, the underlying ideas of general knowledge, integration, synthesis, and unified science developed in ancient philosophy. "Interdisciplinary," nonetheless, is a twentieth-century word. The earliest dictionary citations are references to a December 1937 issue of the *Journal of Educational Sociology* and a subsequent notice regarding postdoctoral fellowships of the Social Science Research Council (SSRC). Yet, ideas of "interrelation," "interfiliations," "intercommunication," "cross-relationships," and "interpenetration" appeared in the social sciences during the 1920s (Frank, 1988, pp. 93-94). In the previous decade, the idea of integrated curricula also appeared in the first general education reform movement in the United States. The current plurality of activity is the result of developments that have made heterogeneity, hybridity, complexity, and interdisciplinarity characterizing traits of knowledge in the latter half of the twentieth century (Klein, in press).

Mapping interdisciplinary activities can be as mind boggling as serving their needs. They comprise a complex and contradictory set of practices located along shifting coordinates (Gunn, 1992, p. 249). Moreover, despite a large literature on the subject, there is no consensus, although there are authoritative terminologies and typologies (for an introduction to the literatures, see Klein, 1994). Differences emerge because activities vary not only across domains but also within them.

In the social sciences, for instance, the earliest prominent interdisciplinary approaches included the unity of science movement, the culture-personality movement, and behavioralism. Throughout the modern history of the social sciences, hybrid domains, such as social psychology and symbolic interactionism, have continued to form. In recent decades, a notable shift from physical processes to symbolic forms has occurred, heightening interactions with the humanities. Clifford Geertz (1980) commented on this "reconfiguration" of the social sciences in the aptly titled and widely read "Blurred Genres."

In the humanities, the ideas of integration and synthesis have strong historical roots—i.e., from the works of Plato, Aristotle, and the Renaissance humanists to early twentieth-century approaches to general education. One of the oldest interdisciplinary fields, American studies, evolved out of English and history departments. More recently, the humanities have experienced a marked increase in genre mixing. Social contextualizations of once discrete disciplinary objects, such as artistic works and literary texts, have blurred traditional boundaries, while new fields, such as feminism and cultural studies, have created "critical interdisciplinarities" that oppose traditional notions of unity and organic relation.

In science, historical precedents range from agricultural research and the Manhattan Project to space research and new work in manufacturing, biotechnology, and computer sciences. New theories, from plate tectonics to chaos, have also had an impact on traditional disciplines of science, and new hybrid interdisciplines, such as materials science and molecular biology, have continued to form. The complexity of modern research problems is often cited as the reason for heightened interdisciplinarity in science today. Yet, with equal force, pragmatic economic and technological problems have stimulated widespread crossing of traditional divisions of science and technology.

Even this thumbnail sketch suggests that interdisciplinary history is not separate from disciplinary history. The dominant pattern of knowledge growth over the course of the century has been the fracturing and refracturing of disciplines into new specialties (Scott, 1984, p. 6). Specialization has been a self-amplifying phenomenon, resulting in 8,530 definable knowledge fields by the year 1987 (Clark, 1995, p. 245; Crane & Small, 1992, p. 197). Yet, while the long-term trend of academic institutions has been in the direction of greater professionalization, departmentalization, and fragmentation, a counter tendency has appeared—the proliferation of crossfertilizations, overlaps, and exchanges (Dogan & Pahre, 1990, p. 85). As a direct result, members of traditional departments are showing up in libraries these days with interdisciplinary needs spawned by new developments in their disciplines and professions, as well as interdisciplinary fields that do not appear on standard organizational charts.

Widespread boundary crossing and genre mixing have promoted a belief that knowledge is increasingly interdisciplinary. As specialization has expanded into new problem areas, the scope of knowledge has extended into new areas of experience and phenomena (Blume, 1985, pp. 145-46). Intensification of interests in new areas has produced new domains that fall between older disciplines, such as sociobiology and biochemistry and, at the extremes of prior capability, particle physics and cosmology. Extensification of interests has produced new areas that draw together existing disciplines to model more complex phenomena, such as concrete economic and public health problems (Fuller, 1988).

A significant number of new specialties have evolved from crossfertilizations of hierarchically unrelated fields, mission oriented fields, and interdisciplinary subject fields. Examples range from political geography and energy politics to sociology of science and the field of communications (Dahlberg, 1994, p. 60). Interdisciplinary fields constitute a second form of specialization that is focused on areas missed or only partially examined by traditional disciplinary specialties (Van Den Daele & Weingart, 1975, pp. 254-55). In order to study new subjects that do not fit into the domains of established subjects, or even take on the classical

characteristics of a discipline, boundaries have been further redrawn through "ontological gerrymandering" (Davis, 1995, p. 133; Woolgar & Pawluch, 1984; Fuller, 1988, p. 197).

As a result of these developments, disciplines have become epistemologically complex (Clark, 1995, p. 252; Klein, in press, p. 55). Disciplines are deeply fissured sites comprised of multiple strata, and they are often influenced by other disciplines (Easton, 1991). They now routinely experience the push of prolific fields and the pull of strong new concepts and paradigms (Jantsch, 1980, p. 306). As dynamic systems—not static structures—disciplines evolve and adapt to changing environments, producing reformulations of the present body of knowledge (Heckhausen, 1972, p. 83). Research tracks and specialties grow, split, join, adapt, and die in an ecology of ideas and influences (Bateson, 1972, pp. 35-46, 62-79; Abbott, 1988, pp. xi, 33). Conventions of interpretation remain but, as Geertz (1980) observed of the social sciences, they are more than ever built to accommodate a situation that is "at once fluid, plural, uncentered, and ineradicably untidy" (p. 166).

These conditions stem, in part, from a process of hybridization. Hybridization reflects the need to accomplish tasks at the boundaries and in the spaces between systems and subsystems (Gibbons et al., 1994, p. 37). In studying the social sciences, Dogan and Pahre (1990) found more recombinations and border crossings by innovative scholars over the past three decades than in the previous millennium. They attribute the development of hybrid fields to a process of *specialization-fragmentation-hybridization.* As specialization reaches a point of density at the core, defined in terms of relative mass of people, room for innovations opens up at the margins, and innovative scholars recombine specialties across disciplinary lines.

Hybridization is both cause and effect. A relatively recent phenomenon, it produces two types of hybrids:

> (1) formally institutionalized subfields of one or another formal discipline or permanent "cross-disciplinary" committees or programs that regularize exchanges among scholars from different disciplines;
> (2) informal hybridized topics, such as development, that may never become institutionalized hybrid fields. (Dogan & Pahre, 1990, p. 63)

The first type, which encompasses many of the examples already mentioned, is the most visible evidence of interdisciplinary activity. Yet the second type, informal hybrid topics, is an equally important index of change. By 1990, roughly 8,000 research topics in science alone were being sustained by specialized networks that are not always bounded by universities, including specialties that require a concentration of funds, equipment, and personnel that are difficult to contain in traditional locales of teaching and study (Clark, 1995, p. 193). Some topics arise from perceived social problem areas and produce new programs of research and

education. Crime, for example, is a social concern addressed by every social science discipline. Interdisciplinary research is conducted on the subject, and interdisciplinary programs have been organized in criminology and criminal justice. The concept of "area," the basis for area studies, is another topical focus and, in response to labor-management conflicts, research institutes and academic programs in industrial relations emerged. Later, responding to other needs, urban studies, gerontology, and environmental studies emerged (Miller, 1982, pp. 12-20).

Different subjects and topics imply different networks of issues, disciplinary structures, and academic values (Fiscella, 1989). In literary studies, a major site of interdisciplinary activity today, new subjects range from the history of the book and materialism of the body to the semiotics of signification and ideologies of gender, race, and class. Each topic, in turn, attracts and projects further lines of interdisciplinary investigation: "The threading of disciplinary principles and procedures," Giles Gunn (1992) found, "is frequently doubled, tripled, and quadrupled in ways that are not only mixed but, from a conventional disciplinary perspective, somewhat off center" (pp. 248-49). The term "off-center" is much to the point. Hybrid topics are stimulated by, as they further stimulate, queries that do not map easily onto conventional knowledge taxonomies or classification schemes:

> Studies like *The Body in Pain* by Elaine Scarry, for example, have woven psychoanalytic, cultural, materialistic, neo-Marxist, and new-historicist strands of disciplinary interrogation; studies of representation such as Stephen J. Greenblatt's *Shakespearean Negotiations* have drawn into new combinations historicist, reader-response, cultural materialist, hermeneutic, semiotic, and often deconstructionist inter- and cross-disciplinary modes. But in much of the new interdisciplinary scholarship, studies of the body become studies of representation. (Gunn, 1992, pp. 248-49)

The perception that knowledge is increasingly interdisciplinary further derives from daily cross-fertilizations of borrowing tools and instruments, methods and techniques, data and information, concepts and theories. The better-known examples span science and technology, the social sciences, and the humanities:

- computers, lasers, the electron microscope, and techniques of gene splicing;
- statistical methods, formal mathematical models, data sets, and systems engineering;
- game theory, organizational theory, and factor analysis;
- survey and interview techniques, participation/observation, thick description, and *explication du text;*
- evolutionary theory, information theory, structuralism, systems theory, and chaos theory;

- the concepts of role, status, decision-making, information, and communication;
- feminist and Marxist analysis. (Klein, in press, pp. 61-62)

One of the added reasons for increased interdisciplinary activity and significant evidence of the current hybridity and complexity of knowledge is the problems that people work on.

Problems

It is no longer controversial to suggest that research problems fall between the cracks of established disciplines (Chubin, 1976, p. 466). All problems, though, are not the same. In his contribution to Sigma Xi's study of boundary crossing in science, George Reynolds suggested that scientists address three different kinds of problems. His formulation is valid across knowledge fields, not just science.

1. Problems of the first kind: "intellectual problems within a traditional discipline";
2. Problems of the second kind: "multidisciplinary problems that are basically intellectual rather than policy-action in nature but that cannot be successfully undertaken within the boundaries of a single discipline";
3. Problems of the third kind: "distinctly multidisciplinary problems generated increasingly by society and distinguished by relatively short-time courses calling in some cases for a policy-action result and in other cases for a technological quick-fix." (Sigma Xi, 1988, p. 22)

Disciplining is at its strongest in problems of the first kind. The underlying action of disciplining knowledge is control. Control extends across the entire system of disciplinary technologies, from the structure of the curriculum, organization charts, and knowledge taxonomies to choice of dissertation topics, decisions about tenure and promotion, and judgments about publication and the awarding of grants. Disciplines control problems by naming the things that will be attended to and framing the context in which they are attended (Schön, 1983, p. 40). The problem of "poverty," for example, appears simultaneously in economics, policy studies, sociology, and women's studies. Similarly, the problem of "disease" appears in social medicine, anatomy, gerontology, and a host of medical specialties. Yet "poverty" and "disease" are constructed differently in each disciplinary domain. Boundaries are drawn along particular disciplinary, professional, and interdisciplinary lines.

That said, problems are not contained simply or neatly within academic domains. The pull of problems is so strong that they are often depicted anthropomorphically, with researchers following them wherever they may "lead." One of the major effects of interdisciplinary activity has

been to redefine problems of the first kind as problems of the second kind. This reformulation occurred when textuality, traditionally constructed as a literary problem, became a problem in anthropology and sociology. Reformulations of problems exert centrifugal pressure on conventional definitions of disciplinary domain, departmental structure, and individual identity (Halliday, 1992, p. 26).

Geography provides an extended illustration. Over the course of the twentieth century, the discipline has expanded to include subfields of human, cultural, economic, political, urban, and regional geography as well as biogeography, geomorphology, climatology, environmental science, and cartography. Each subfield, in turn, relates to specialties outside the discipline. Current links with sociology, for example, include human ecology, environmental sociology, rural sociology, and urban studies (Dogan & Pahre, 1990, p. 94). As a result of this history, geographers often use the word "interrelation" to describe the problems they address (Bulick, 1982, p. 46). They have also adopted compound names, identifying themselves as cultural, social, behavioral, regional, physical, historical, Marxist, and economic geographers, as well as geomorphologists, climatologists, and human ecologists (Warrick & Reibsame, 1981, pp. 422-23).

Biology is another example. The boundaries of biology's subfields are not always easy to discriminate, and biologists may identify themselves differently from the work they are doing at a particular point and from external definitions of their disciplinary domain. One researcher that Kenneth Ruscio interviewed admitted he might be called a biologist but can no longer do so in good conscience. Another usually replies that immunology is his discipline because that is his research area. Yet he coordinates a cell biology course and admits that he is really a cell biologist even though, in studying how cells function, he is involved in problems that go beyond immunology into genetics (Ruscio, 1985, pp. 14-15). These days an embryologist and a geneticist may be more alike in knowledge, techniques, and interests than two chemists. In this circumstance, is it proper to call the collaboration between a geneticist and an embryologist "interdisciplinary" while classifying the joint work of two chemists who labor to understand each other as "disciplinary" research? (Wolfle, 1981, p. 6). Is the scientist who investigates certain molecular structures of DNA a molecular biologist, a geneticist, a biochemist, or a quantum mechanic? (Swoboda, 1979, p. 53).

Problems of the third kind are widely perceived as the major reason for increased interdisciplinarity. Because their impetus lies outside the boundaries of the academy, they are outside the scope of classical problems of the first kind or intellectual problems of the second kind. In 1972, when the Organization for Economic Cooperation and Development (OECD) presented results of the first international survey of interdisciplinary research and education, the first reported force driving

interdisciplinarity was the development of "science," meaning knowledge in the European sense of the word (OECD, 1972, p. 44) or, by inference, problems of the second kind. A decade later, when presenting results of an international survey on relations between universities and their communities, the OECD declared that exogenous interdisciplinarity now takes priority over endogenous interdisciplinarity (OECD, 1982, p. 130). The term "endogenous" refers to the internal development of knowledge, the term "exogenous" to problems originating in the community and its practical needs.

The OECD's assertion of pragmatic primacy is valid to the extent that demands for social and economic relevance have heightened the legitimacy of practical problem-solving projects, many of them funded by public money. The share of problem- and mission-oriented research in the university has increased to the point that a significant portion of basic research now includes the adjective "mission oriented" (Ruscio, 1985, p. 16). In order to accommodate this type of research, the number of problem-focused structures and collaborative work modes has increased. Disciplines involved in mission-oriented research are also exhibiting fuzziness at their boundaries, and, in some areas, knowledge production is no longer occurring strictly within disciplinary boundaries. Leading examples include the Human Genome Project and the fields of biotechnology, molecular biology, risk assessment, and technology assessment (Gibbons et al., 1994, pp. 138, 147).

Problems of the third kind are also prominent in professional fields. The problems professionals face in day-to-day practice pull research away from disciplinary formulation as problems of the first kind. By their very nature they are open-ended, multidimensional, ambiguous, and unstable. Considered "wicked" and "messy," the problems at the heart of many professional fields cannot be bounded and managed by classical approaches to the underlying phenomena (Mason & Mitroff, 1981; Rittle & Webber, 1973). In the field of planning, for instance, modern planning theory was formed when the special model of rational behavior adopted by neoclassical economics developed into a general theory of rational decision-making. Despite its scope and wide applicability, though, the theory was framed by the paradigm of economic rationality. The gap between technical rationality and the day-to-day problems of practice has stirred challenges to the paradigm. The challenges, often cast as signs of disciplinary crisis, include interdisciplinary approaches, ecological concepts, systems theory, and contingency models that advocate contextually determined decision making (Klein, 1990/91, p. 30).

In the curriculum of professional schools, the problems of interrelating constituent elements are not usually discussed in terms of interdisciplinarity per se, but rather as "integration," "coordination," or the role of "service" courses taught by other departments. Yet, the broader

trend toward interdisciplinarity is being reinforced by growing inclusion of new elements in professional courses, management studies in engineering, social studies in medicine, and foreign languages or computing in others. In keeping with problems of the third kind, interdisciplinarity in professional schools is usually perceived in pragmatic or organizational terms, not theoretical terms (Squires, 1992, p. 206).

Both problems of the second and third kinds posit alternative organizations of knowledge. Exogenous interdisciplinarity forever questions the disciplines on the validity of demarcations they apply to life. If the concept of health, for example, is the starting point for interrogating biological sciences, no boundaries can be accepted between physiology and ethnology or between biology and psychology. If the starting point is the concept of education, the interaction of sociological and psychological aspects or the functions of an institution and teaching practices are perceived as necessary. Similarly, industrial practice can no longer be viewed as simply applied physics or applied economics. Each time, "reality" must be approached from different angles and a vital role accorded to relations among them (OECD, 1982, p. 130). Yet, despite the alternative conceptual status of their underlying categories of knowledge, such as "health" or "ecosystem," problems of the third kind are usually treated in instrumental terms, rendering interdisciplinarity an empirical problem.

When interdisciplinarity is treated as an epistemological problem, a different condition of knowledge exists. Bryan Turner's (1990) analysis of the medical curriculum illustrates the difference. Interdisciplinarity in social medicine and sociology of health emerged as an epistemological goal. Researchers focus on the complex causality of illness and disease and the corresponding assertion that any valid therapeutics must be based in a holistic view of the patient. In research centers based on teamwork and solving social and technological problems, interdisciplinarity has been an unintended consequence of economic necessity, not scientific theory. A pragmatic stance renders universities instruments for the production of skills, replacing questions of epistemology with the pragmatics of reliability, efficiency, and commercial value.

Both problems of the second and third kinds also propel movement away from purely disciplinary criteria, although the shift is more widely associated with problems of the third kind. Aant Elzinga (1985) coined the term "epistemic drift" to mark the movement from strictly internalist criteria and reputational control to externally driven criteria that are more open to external regulation in the policy arena (p. 209). Public interest in exogenous problems and political intervention in order to create new facilities to address those problems have propelled interdisciplinary activity in areas of high technology, genetics, space, and cancer research. In this instance, interdisciplinarity is drawn more closely to the problem

of knowledge policy, not epistemology (Fuller, 1993, p. 33) or critique, which is highlighted in critical interdisciplinarities. In this instance, interdisciplinarity serves the political economy of national needs and market trends.

Similarly, Burton Clark (1995) speaks of "restless research." Restless research moves out in many directions from traditional university settings. As an increasing share of research activities becomes located outside teaching departments and outside universities, a "research drift" is occurring (pp. 12, 195). Gibbons et al. (1994) theorize this development as a new mode of knowledge production. Mode 1, the traditional form of knowledge production, is primarily academic, homogeneous, and hierarchical. Comprised of ideas, methods, values, and norms embodied in the Newtonian model of science, it emphasizes disciplinary boundary work and certification. The new mode is framed by the context of application and use. While it is still at an early point, the effects of Mode 2 have already weakened disciplinary and institutional boundaries.

Mode 2 is characterized by closer interaction among scientific, technological, and industrial modes of knowledge production. It is non-hierarchical and transdisciplinary, and it is distinguished by heterogeneously organized forms. Research problems are not set within a disciplinary framework. Human resources are also more mobile, and the organization of research is more open and flexible. In contrast to the simple sharing of resources in Mode 1, Mode 2 entails ceaseless reconfiguration of resources, knowledge, and skills. Each new configuration becomes a potential source of knowledge production that is transformed, in turn, into the site of further possible configurations in a process of ceaseless reconfigurations. In a dynamic and socially distributed system with feedback loops, markets set new problems more or less continuously.

Mode 2 is strongly associated with "science going to be market," but the underlying process is apparent in the humanities as well. The growing fuzziness of disciplinary boundaries that is characteristic of postmodernism, social contextualizations, the crossing of boundaries between elite and mass/popular forms of culture, the heterogeneity of forms and sites of knowledge production, and the impact of the massification of research and higher education are major indicators. In addition, powerful interdisciplinary movements, such as textualism and the *Annales* school of society history, have reconfigured traditional humanities disciplines and their relations with social sciences for a wider range of reasons than Gibbons et al.'s emphasis on utility allows.

Epistemic drift, restless research, and Mode 2 knowledge production are linked, as well, to the second and third questions—What are the forms of interdisciplinary activities? And, what are their institutional locations?

Institutional Structure

The location of interdisciplinary activity may be visualized in terms of a spectrum. At one end of the spectrum, overt visible activities appear in the surface structure of institutions. At the other end, concealed invisible activities appear in the shadow structure (Klein, in press). In reviewing the track record of interdisciplinary experiments of the 1960s and 1970s, Keith Clayton (1984, 1985) concluded that little progress had been made in "overt interdisciplinarity." The "concealed reality of interdisciplinarity," though, suggests that interdisciplinary studies are probably flourishing most where not labeled as such—e.g., in medicine, veterinary science, agriculture, oceanography, and geography. Behind the "'subject' façade," interdisciplinarity is flourishing.

The most visible forms are self-consciously interdisciplinary universities, colleges, programs, centers, laboratories, and other research facilities such as experiment stations. Some are sufficiently large or prestigious to be regarded as part of the surface structure of a particular college or university. In the curriculum, they include interdisciplinary approaches to general education, new fields and specialty interests, professional training, the educational functions of research centers, individual courses and course segments, as well as internships, practica, and travel-study (for an overview of research activities, see Klein, in press; for an overview of the curriculum, see Klein, 1990, pp. 19-54; Klein & Doty, 1994; Klein & Newell, 1996).

Invisible and concealed activities are embodied in shared interests, common problem domain, the borrowing of methods and tools, faculty learning communities and networks, individual participation in interdisciplinary fields, and team teaching and collaborative research. From the perspective of buildings and equipment, they include shared use of facilities, instrumentation, and databases. The least visible part of the shadow structure is the grassroots presence in disciplines. Activities at this level encompass the interdisciplinary traditions and practices of a discipline, borrowing, problem-focused research, and connection-making in the curriculum. The Association of American Colleges and Universities' (AACU) three-year study of the undergraduate major yielded ample evidence of connection-making—i.e., from problem-focused study and cultivation of integrative skills to contextual inquiry and capstone courses (AACU, 1990).

Activities at the level of disciplines may go unrecognized because faculty often retain traditional labels. Yet their migrations across research specialties are an important form of interdisciplinary activity. As interests change, new discourse patterns emerge, hybrid knowledge communities form, and disciplines fragment along other lines. A member of a French department who was educated in traditional modes of reading literary texts may migrate to a new hybrid specialty such as interpretive theory, or contribute to an established field such as women's studies, or move to a

new field such as cultural studies. A member of a chemical engineering department may temporarily join a team designing a new urban transportation system, or develop a new line of research on chemical properties in manufacturing design, or relocate to a materials science program or research center (Klein, in press).

The evidence lies not only in the activities of persons but also in institutional structures. Since 1945, the number and variety of institutions devoted to knowledge production have increased dramatically (Gibbons, et al., 1994, p. 141). For the first half of the twentieth century, disciplines were contained and controlled within departmental units. As disciplines have differentiated into increasing numbers of specialties, they have become decentralized into smaller units that neither certainly nor inevitably lie within conventionally defined boundaries. In one public research university, the subject of biology was spread across thirteen discipline-based departments and seventeen interdisciplinary programs (Clark, 1995, p. 142). Alternative sites of research—programs, centers, institutes, and laboratories—have further weakened disciplinary control over subject definition, conceptual approaches, cognitive structures, goals, and norms (Whitley, 1984, pp. 12, 18-20). Three of the most prominent institutional sites are research centers, educational programs of interdisciplinary studies, and new alliances that bridge the academy, industry, and government.

Centers augment the traditional department structure, primarily for the purpose of conducting research. They also collect resources that are used directly for research, such as computers, survey-research facilities, small-group laboratories, specialized libraries, and specialized data. The multi- and interdisciplinary nature of problems is often highlighted when research is located in centers: when, for instance, a polar research center addresses problems of ice core research, polar ecology, Antarctic tectonics, or glaciology (OSU, 1991, p. 18). Most centers, though, are either dominated by a single discipline or bring together a multidisciplinary mix of disciplines. In a large center, the portfolio of projects may include a mix of single-discipline projects, isolated or loosely linked multidisciplinary inputs, and some collaborative activity.

Some centers are connected with recognized interdisciplinary fields such as women's studies, Judaic studies, policy studies, and molecular biology. Others serve localized interests such as regional studies, manufacturing and transportation projects, and employment training. Others yet promote research in areas sustained by national and international networks, from polar research, global change, peace and conflict studies to developmental disabilities and cancer research. The collective presence of centers reinforces the view that official partitions of knowledge are too rigid, as demands for task- , mission- , and problem-orientation reinforce the view that centers are not peripheral to, but a necessary part of, the system of knowledge production.

The same claim is made about educational programs of interdisciplinary studies. Over the past two decades, a notable increase in interdisciplinary approaches to general education has been occurring in the United States. The greatest growth in subject matter areas of general education encourages interdisciplinary approaches in areas such as international studies, American multicultural and gender studies, and the inherently synoptic areas of historical consciousness and ethical understanding (Casey, 1994, p. 56). In the United States, interdisciplinary studies are also being mainstreamed in the form of topical first-year seminars, required core courses, advanced courses on problems or intellectual themes, and senior "capstone" seminars and projects (Stember, 1991, p. 3). In Europe, renewed calls for coherence and connectedness are being heard in the professions and across university subjects. The contexts include environment and ecology; energy, health, Third World; and development policies; information technology; media studies; European unification; and intercultural communication (Huber, 1992b, p. 297).

Like centers, many programs of interdisciplinary studies are connected with new hybrid fields, drawing research and education into parallel trajectories. Examples encompass a range of subject and problem areas, from gerontology and environmental studies to cultural and urban studies. Some fields are quite new. Others have developed to the point that they utilize discipline-like strategies. Cognitive science, for example, has a professional association, an identifiable set of journals, degree programs, and a special library classification. The educational programs that represent these fields are the curricular face of new categories of knowledge. Categories of knowledge are institutions, not in the conventional sense of buildings and organizations but a set of constructed and maintained marks in cultural space. The underlying epistemological categories of interdisciplinary studies—such as "urban," "environment," "border," "area," "women," and "culture"—appear in a number of disciplines in partial form. Alternative organizations of knowledge in order to develop them in interdisciplinary fashion have been a major aspect of knowledge production over the latter half of the century.

Alternative organizations of knowledge cannot be fully understood without factoring in socioeconomic and political realities. Conditions of enactment in the interiors of institutions differ widely (Clark, 1995, p. 239). Hence, the same field does not assume the same form from one campus to another. Correspondingly, perceptions of faculty and students differ, a major factor in shaping their sense of information needs. The variable conditions of interdisciplinary studies are especially striking in the United States with its system of over 3,400 post-secondary institutions (Oakley, 1992, p. 282). American studies, to illustrate, may be the primary research interest of a single faculty member, a cross-departmental program, a research center, or a well-established program offering both undergraduate and graduate degrees. Period studies, ranging from the

ancient world to the late twentieth-century or even future studies, may structure departmental curricula or be enclaved in a research center. Likewise, textual and discourse studies, comparative literature, and biochemistry may occupy discrete domains or be dispersed. Biochemistry is sometimes structured as an independent department, sometimes linked to biophysics, joined with physiology, and sometimes organized by an interdisciplinary committee composed of members of departments of biology and chemistry (Bechtel, 1986, p. 16).

In the realm of problems of the third kind, alliances bridging academic, governmental, and industrial sectors have gained increased presence over the past two decades. They include not only familiar structures (science parks, experiment stations, and research centers) but also new structures (offices of technology transfer, industrial liaison programs, joint mergers, and entrepreneurial firms), new affiliations (patent and licensing operations, research consortia, teamwork, and contract research), and new linkages (industrial appointment of academics, venture capital for entrepreneurial faculty, university equipment projects, and the flow of personnel across academic and industrial laboratories) (Klein, in press, p. 182).

As Gibbons et al.'s (1994) theory of Mode 2 knowledge production suggests, the older boundary between basic science and applied science is also being blurred by heightened interplay between differing forms of scientific and technological investigation and of investigative technique and product development. Science and higher education, Clark (1995) adds, have been drawn into fuller and more complicated relationships with patrons who have their own agendas and expectations, especially in fields requiring expensive equipment and large bureaucracies. In some cases, government interests have encouraged a drift of research out of higher education into a wider field of institutions and sites across civilian government agencies, the military establishment, the nonprofit sector, and industry. In the United States, this form of research drift has been slowed by the historic entrenched strength of American research universities as places of inquiry, in contrast to greater reliance on separate research institutes in other countries. Even in the United States though, a significant share of research is appearing outside the university framework (Clark, 1995, pp. 2-4, 197, 208). Clearly, institutional complexity parallels knowledge complexity, yet simplified views often prevail.

Representing Knowledge

Simplified views add to the problem of operational realities that outrun old expectations, especially older definitions and historic ideals that view one part or function of the university as its "essence" or "essential mission." The thrust of complexity has been in the direction of turning universities into multiversities, then into conglomerates. Universities, pushed and pulled in many directions, are less likely to be characterized

by the tight linkage of unitary organization and more by the loose coupling that is characteristic of federations. The main commodity of higher education—knowledge—becomes more diffuse, opaque, incoherent, and centrifugal. As a result, older images of unifying central values and institutional simplicity no longer apply to the fast-changing reality of opaque complexity. The problem of responding to complexity and contradiction is not simply a matter of achieving philosophical reconciliation of ideas. It is overwhelmingly a problem of organization (Clark, 1995, pp. 154-55, 189, 247-48; Scott, 1991).

General systems theory, Klein and Newell (1996) suggest, provides a metaphor for conceptualizing what is happening. Briefly stated, simple systems operate according to a single set of rules. Even if they have multiple levels, connections are arranged in a hierarchy. Complicated systems are variations on the themes of simple systems. Complex systems, in contrast, have nonhierarchical structures. They obey multiple conflicting logics, utilize positive and negative feedback, reveal synergistic effects, and may have a chaotic element. The terminology and methods for understanding the system change as those in the system move through it. To understand what is happening, reductionist thinking must be replaced by nonlinear thinking, pattern recognition, and analogy. Activities may be interconnected in a shifting matrix, replete with feedback loops and unpredictable synergistic relationships in an array of nested contexts (Klein & Newell, in press).

Signs of the shift from simplicity to complexity in academic systems echo across countless reports of learned societies, research advisory bodies, and educational commissions. In its recent report, the Commonwealth of Virginia's Commission on the University of the 21st Century recalled the words of one university president. The fact that much exciting teaching and research is called "interdisciplinary," he lamented, is a mark of shame. Concluding that the disciplines are no longer adequate to what we know and the problems we must solve, the commission called for nothing less than a basic transformation in the ways Virginia thinks about higher education, the ways colleges and universities think about their responsibilities, and the ways faculties think about knowledge and their disciplines (*Case for Change,* n.d., pp. 2, 13).

Language, as librarians well know, is another sign of change. New terminology has been developed to classify interdisciplinary interests. The term "aggregative approach," for example, labels fields such as gerontology and urban research, which share the focus of different disciplines and exhibit a methodologically and theoretically integrative approach. Usually, though, indicators are more subtle, and obvious keywords—"multidisciplinary," "interdisciplinary," "crossdisciplinary," "transdisciplinary," and kindred labels—are not used. New words enter the vocabulary and old words take on new meaning, marking shifts in perspective and new ways of seeing (Suleiman,

1980, p. 3). "The interface between physics and chemistry," the National Research Council reported recently, "has been crossed so often in both directions that its exact location is obscure." Passage across the interface is signaled more by gradual changes in language and approach than sharp demarcations in content. These changes have been a source of continual advances in concept and application all across the science of molecules and atoms, surfaces and interfaces, and fluids and solids (National Research Council, 1986, p. 53).

Metaphors are equally revealing. Whether implicit or explicit, arguments about knowledge are often guided by metaphors (Becher, 1990, p. 333). In the latter half of the century, metaphors of knowledge description have shifted from the static logic of foundation and structure to the dynamic properties of network, web, system, field, and topological metaphors that describe relations among elements, such as joints, points of connection, overlaps, interconnections, interpenetrations, breaks, and cracks (Goldman, 1995, pp. 222-23). In descriptions of interdisciplinary work, a dual rhetoric appears. Metaphors of place—turf, territory, boundary, and domain—call attention to the ways that categories and classifications stake out differences. Metaphors of connection call attention to the crossing and reconstruction of categories and classifications.

"Interdisciplinarity," Roland Barthes (1977) pointed out almost three decades ago, "is not the calm of an easy security." There are few genuine breaks. In contrast to a mere declaration or wish, interdisciplinarity begins *effectively* when the solidarity of existing disciplines breaks down. This breakdown may occur suddenly, even "violently," through disruptions of fashion, and the interests of new objects and new languages that lack a place in the fields being brought together. The starting point is an "unease in classification." From there a "certain mutation" may be detected. This mutation must not be overestimated, however: "it is more in the nature of an epistemological slide than of a real break" (Barthes, 1977, p. 155).

In a companion metaphor, William Paulson (1991) likens interdisciplinarity to the concept of self organization from noise. The metaphor comes from information theory. When there is noise in an electronic channel during transmission, the information received is diminished by a function known as ambiguity of the message. The message received is neither pure nor simple. Importing terms and concepts from other disciplines creates a kind of noise in the knowledge system. Perceived as unwanted noise in one context, variety and interference can become information in a new or reorganized context. Noise is a signal: "What appears to be a perturbation in a given system turns out to be the intersection of a new system with the first" (Paulson, 1991, p. 44).

Critical interdisciplinarities dispute and disorder conventional understandings of relations between the most fundamental concepts of knowledge description—between origin and terminus, center and periphery, fo-

cus and margin, inside and outside (Gunn, 1992, p. 249). Yet perturbation, disequilibrium, and noise occur to some degree in all interdisciplinary activities, whether in the simple borrowing of a method or concept or in the creation of a new social and cognitive structure to solve a problem. When the day is over, the computers are turned off, the indexes restaked, and the library doors locked, the problem of fit remains. If the structure must be changed to accommodate new fields and new needs, Caldwell (1983) admonishes, perhaps the structure itself is part of the problem.

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