'Interdisciplinary strategies' in U.S. research universities

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Abstract   In the context of increasing support for interdisciplinary modes of research, many in the policy, scientific, and academic communities propose that universities should change structurally to reduce the barriers to investigation that involves researchers from multiple disciplines. This paper examines 'interdisciplinary strategies' in U.S. research universities—deliberate efforts to spur collaborative research across traditional departmental and disciplinary boundaries, including the creation and adaptation of university policies, practices, and structures. It identifies and analyzes the use of incentive grants to initiate new interdisciplinary units, the establishment of 'campus-wide institutes' that steer campus investments in interdisciplinary areas, and new modes of faculty hiring and evaluation. Illustrative examples are provided, and the implications of these strategies are discussed.

Keywords   Research universities · Interdisciplinary research · Organizational strategies · Organized research units · Research centers and institutes · Organizational change

Interdisciplinarity has become a laudable goal for federal agencies, scientific associations, industry, and academic leaders in the US. Proponents contend that academic institutions risk impairing scientific advancement and diminishing the contributions of science to society by retaining traditional organizational forms and modes of work associated with disciplinary specialization (National Academies 2005; Rhoten 2004). A sense that the 'needed' science does not follow from the ways of organizing research in academia underlies federal, state, and philanthropic funding of interdisciplinary centers (Feller 2005; Geiger and Sá 2005; Hackett 2000)

   Two influential academic associations—the National Academies of Sciences and the Association of American Universities—recently released reports on how universities can facilitate interdisciplinary research. The reports present examples of practices from several

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institution; universities are called upon to reshape themselves to break the structural barriers that prevent researchers from engaging in interdisciplinary collaborations across organizational boundaries (AAU 2005; National Academies 2005). The reformed university would purportedly allow for leaps in scientific progress and greater economic and social benefits to society. On the other hand, there is also skepticism about the rhetoric of interdisciplinarity in academia (Weingart 2000). A particularly skeptical view is that if interdisciplinarity were to significantly affect the disciplinary arrangements of academia this would have happened already, given the historical cycles of support to the former (Abbott 2001).

Creating adequate environments for the practice of interdisciplinary research is often viewed as a managerial problem that requires academic leadership. Rhoten (2004) claims that there is no lack of external support to or motivation from the faculty to engage in interdisciplinary research, but of systematic implementation of measures to facilitate such work. Feller (2002, pp. 113–114) asserts, ''where an interdisciplinary culture does not already permeate the institution, or where such culture in threatened, central administration action is needed to nurture heads who pursue collaborative research relationships that cross boundaries.'' In this context, promoting interdisciplinarity is viewed as an organizational problem—enabling collaborative research among faculty from different disciplines.

Recent studies indicate the widespread adoption of interdisciplinarity as an institutional goal or strategy among research universities over the past 10 years (Feller 2002; Brint 2005). These studies noted that most leading universities boast commitments to fostering interdisciplinary activity on their campuses, while some institutions aspire to differentiate themselves as propitious places for interdisciplinarity. Feller (2004) has suggested that those institutions more apt at effectively adapting to interdisciplinary thrusts may gain an edge in the research market if current federal funding trends persist. The political and financial support to, and the proclaimed interest of academic leaders in interdisciplinarity suggest the potential for a creative tension between institutional aspirations and traditional academic structures (Brint 2005). Such tension would generate alternative organizational arrangements, policy priorities, and sources of recognition to academic research. While it is known that many universities have incorporated interdisciplinarity in their planning documents since the late 1990s, we know less about whether and how such emphasis has brought about organizational change.

This study investigated organizational strategies to foster interdisciplinary science in US research-intensive universities: what are they? How do they change traditional norms, organizational structures, and practices? What are their implications? This paper identifies and characterizes 'interdisciplinary strategies'—deliberate efforts to spur collaborative research across traditional departmental and disciplinary boundaries, including the creation and adaptation of university policies, practices, and structures. The focus is on strategies at the institutional level, rather than at the college or departmental levels. This was a two-phased study, involving an initial survey of institutional documents for 100 research-intensive universities; from this analysis, five institutions were selected for campus visits, where distinctive strategies were investigated in greater detail. While space limitations do not allow for an extended account of the cases, this paper distills key insights from them to illustrate more general patterns. The section below sets the background for the study's findings by discussing the disciplinary basis of university organization, the problem it raises for interdisciplinary research, and some general understandings about interdisciplinary centers and institutes.

Interdisciplinary research as an organizational problem

The disciplinary departmental nexus

The modern research university finds in the nexus between disciplines and academic departments its basic organizational framework (Blau 1994; Clark 1995). This association between the social structure of disciplines and the organizational structure of academic departments became institutionalized early on in the history of American universities. Veysey (1965) locates the origins of clear departmental structures at leading universities in the 1890s. Thereafter, Geiger (2004, p. 37) argues, disciplines and departments ''had powerful reciprocal effects upon one another'' as both institutions developed, with the growing authority of one reflecting upon the other. The number of disciplines and fields of study grew throughout the 20th century, creating their own professional associations, conferences, journals and gaining departmental homes in universities (Clark 1996). For all the expansion and diversification of knowledge production inside and outside of academia (Gibbons et al. 1994), disciplines and their departmental counterparts are remarkably resilient across time and space.

Abbott (2001) asserts that the resilience of disciplines results from the 'dual institutionalization' of the macrostructure of disciplinary labor markets and the microstructure of individual universities, each containing similar departments. University departments are both 'producers' and 'consumers' of academic professionals in these disciplinary labor markets. Thus, Abbott argues, there are disincentives for universities to deviate from established disciplinary-departmental forms, since that may threaten the academic career prospects of Ph.D. graduates. He contends that 'the current social structure of disciplines will endlessly re-create itself' (p. 127) as departments participate in and draw faculty from the disciplinary labor markets. Similarly, Turner (2000) points to academic labor markets as the source of similarity among and continuity of departmental organizational forms. The idea that disciplines reunite common intellectual cores is debatable for Turner, who claims that popular distinctions between interdisciplinary and disciplinary forms of knowledge are 'the product of the historical accidents that created disciplines in the first place' (p. 52). Abbott (2001, p. 126) notes that Carnegie Mellon University is successful but unique as 'perhaps the only major university in the US organized in nontraditional departments.' One can add to the list Rockefeller University, a specialized institution that historically adopted interdisciplinary forms of organization (Hollingsworth and Hollingsworth 2000).

The insights of institutional theorists illuminate these views on disciplines and their nexus with university departments. Institutional theory highlights the historically contingent and contested nature of social institutions, such as (higher) education systems and their particular configurations (Powell and DiMaggio, 1991; Meyer and Rowan 2006). It emphasizes cultural-cognitive and political processes that shape the selection and endurance of particular institutional arrangements. Institutionalized arrangements come to be seen as 'natural' and define legitimate ways of organizing and transacting. Institutional theorists highlight the path-dependent nature of institutions, whose pace of change is generally slow, regardless of whether they generate the most efficient outcomes or not. Legitimacy, as opposed to efficiency, is the main currency of institutional survival. But power and interests are also important forces in the continuity of institutions, which may serve the interests of dominant coalitions that may oppose and prevent institutional change.

At the organizational level, Zucker (1987) argues that institutional elements (e.g., actions, roles, structures) are resistant to change, are maintained without justification for

long periods of time, and are easily transmittable to new organizational members. Change in prevailing arrangements entails overcoming 'sunk costs' associated to longstanding patterns of organization, and the taken-for-granted assumptions that sustain the status quo (Jepperson 1991). Viewed from an institutional perspective, the presumable benefits of prevailing arrangements in academic structure, such as the quality control afforded by discipline-based departments (Turner 2000; Feller 2004), have a normative, rule-like status for university actors. Change is possible, but requires agents to question the underlying assumptions of traditional norms and to counteract ingrained modes of thinking, habits, and traditions.

Since its early institutionalization, the departmental structure has organized and legit-imated academic work, despite cyclical interest in interdisciplinary modes of scholarship (Klein 1990; Lattuca 2001). Through the control over faculty appointment, promotion, and tenure decisions, departments shape the intellectual capital of the campus in tune with the cultures, norms and intellectual orientations of the disciplines. Universities also derive recognition and prestige through the collective achievement of their departments as probed by discipline-based mechanisms (e.g., the National Research Council's assessment of doctoral programs). Ranking and rating systems often rely on peer assessments that capture and reward disciplinary achievements and departmental reputations (Feller 2002).

Barriers to interdisciplinary research

Proponents of interdisciplinarity have historically argued that the disciplinary mode of research production leads to an excessive fragmentation of knowledge (Klein 1990; National Academies 2005; Caruso and Rhoten 2001). The continuing specialization of fields is reflected on the organizational structure of universities. Clark (1995, p. 245) asserts, ''the steady decomposing of disciplines into specialties, and then of specialties into more specialties, operates across universities as an uncontrollable, self-amplifying phenomenon. Disciplinary subdivision is a powerful pressure for departmental substructuring.'' This phenomenon is often criticized as leading to the formation of departmental 'silos' whose researchers do not communicate across disciplinary and organizational boundaries.

While such critique has been usual of late, it is far from a new. About 40 years ago, Jencks and Riesman (1968, pp. 523–525) argued for the need for more 'mobility and anarchy' among disciplines and sub-disciplines. They contended that the former are eminently administrative units, while the latter are the true intellectual units of the uni-versity. Jencks and Riesman called for a continuing process of assembling and reassem-bling faculty whose interests intersect on the basis of research problems, to offer new kinds of Ph.D. programs. Far from generating a static, problem-driven organizational alternative to academic departments, Jencks and Riesman proposed that universities should engage in a continuous state of creative destruction, akin to Jefferson's revolution every 20 years. Interestingly, a similar notion is suggested in the recent National Academies (2005, p. 174) report, when it suggests ''a more dramatic or 'revolutionary' vision of interdisciplinarity … in which institutions strive for a more complete integration of disciplines, institutions 'without walls,' a high degree of flexibility and mobility for students and faculty, and research efforts that are organized around problems rather than disciplines.''

Reviews of interdisciplinarity in academia suggest that this nexus between disciplines and departments, briefly characterized above, produces several disincentives for interdis-ciplinary research (Klein 1990; Lattuca 2001; Feller 2002). As noted above, the very 'production' and 'absorption' of researchers in the disciplinary labor markets constraint the

appearance and career success of a relatively large number of interdisciplinary scientists. At the individual level, early training and socialization in doctoral programs is conducive to disciplinary specialization. So is the academic reward structure, based upon the judgments of disciplinary peers. Clark (1984) describes university professors as holding multiple allegiances to departments and the national and international networks of disciplines and research fields, from which they derive professional recognition. Interdisciplinary research is usually regarded as harder to evaluate in terms of funding proposals, manuscript submissions, and published work (Feller 2006; Mansilla et al. 2006; Lamont et al. 2006; Langfeldt 2006). Faculty pursuing interdisciplinary research may find it hard to secure funding, publish, and to have publications recognized by disciplinary peers.

Thus, the institutionalized arrangements under discussion generate 'transaction costs' for university faculty to conduct interdisciplinary research, particularly in collaboration with colleagues from different academic units. Some are inherent to the process of collaboration, such as communication issues, the management of research teams, and the need to catch up with the knowledge and methods of other fields. Others relate to the organizational context of universities, such as resource allocation and credit systems that do not fund and/or reward individuals and units for crosscutting collaborations; evaluation, promotion, and tenure processes that do not properly evaluate or undervalue collaborative and interdisciplinary work; and departmental and campus cultures and climates that are indifferent or hostile to such activities. Allowing for variation across fields and institutions, these are recurring issues in reviews on interdisciplinary research in American universities (see National Academies 2005, Feller 2002; Lattuca 2001, pp. 35–37).

Interdisciplinary centers and institutes

In order to circumvent such difficulties, universities have traditionally created interdisciplinary research centers and institutes (also called organized research units [ORUs]) (Ikenberry and Friedman 1972; Geiger 1990; Stahler and Tash 1994). Organized research units display huge variability in goals, purposes, functions, organizational structures, and underlying activities. Several studies have attempted to make sense of the diversity of centers and institutes by proposing typologies (Kruytbosch 1970; Ikenberry and Friedman 1972; Alpert 1985; Geiger 1990; Bozeman and Boardman 2003; Mallon and Bunton 2005). Some authors have observed that interdisciplinary centers are often problem or mission-oriented, accountable to external sponsors (Kruytbosch 1970; Alpert 1985); others contend that size is a key variable shaping the nature of interdisciplinary units, as described in Table 1 (Epton et al. 1985; National Academies 2005).

While they are hardly a new phenomenon in American science, centers have only grown in numbers and importance over the decades (Geiger 1990). The biomedical research enterprise is particularly reliant on centers, given the growing interdisciplinarity in the life sciences, the funding patterns of the National Institutes of Health, and the business model of medical schools (Mallon and Bunton 2005). In the 1980s, survey studies suggested a prevalence of disciplinary work in large samples of ORUs (Friedman and Friedman 1982, 1986). Recent surveys of centers in medical schools suggest an increase in the proportion of units dedicated to interdisciplinary research (Mallon and Bunton 2005). Interdisciplinary centers are increasingly important in other areas of science and technology as well. The National Science Foundation Engineering Research Centers and Science and Technology Centers are regarded as powerful programs in changing the culture in academia and industry towards multi-institutional, interdisciplinary collaborations (Bozeman and

Boardman 2003). Bozeman and Boardman (2003) argue that federal funding agencies (and the NSF in particular) have helped institutionalize the ''multi-discipline, multi-purpose,'' center, whose purposes include collaborating with industry, resource and equipment sharing, and technology transfer.

Despite the multiplication of interdisciplinary ORUs overtime, some observers are frustrated by the lack of administrative leadership in bringing about organizational change to facilitate interdisciplinarity in universities. Exhortations for change include calls for greater autonomy for interdisciplinary centers (Rhoten 2003) and the diffusion of 'best practices' (AAU 2005; National Academies 2005). Other arrangements at the individual faculty level include the granting of joint-appointments in two departments, and grants for faculty to temporarily join a department in a different discipline to learn more about it. Such arrangements are still marginal in scope and scale within and across institutions.

Organizational strategies to foster interdisciplinary research

Most universities still promote interdisciplinary research chiefly through the establishment of ORUs that draw on faculty from multiple departments. Novel models of support and organization have appeared, although distinctions between the 'old' and the 'new' are tricky given the scant and scattered knowledge of interdisciplinary centers and institutes. The arrangements identified represent subtle evolutions and variations on old themes. Formal and systematic processes to create and fund interdisciplinary ORUs have appeared, and previously undocumented types of such units have gained prominence. While these developments involve significant resources, they do not directly challenge the disciplinary-departmental structure of the university. A few institutions, however, defy earlier assertions that departments retain exclusive control over academic life through hiring and tenure decisions (Feller 2004; Brint 2005). New models of faculty recruitment and evaluation have been implemented, and early signs of dissemination are apparent.

Incentive grants

Several universities have implemented formal funding programs to support the establishment of new inter-departmental and inter-college research collaborations.[1] These may appear as 'seed grant' schemes or as targeted investments within strategic planning efforts. In common is the competitive provision of one-time funding, with the expectation that some level of self-sustainability is achieved in the near future. While the specific approaches vary substantially across institutions, the overall pattern is clear: universities pool resources centrally and redistribute them competitively to form interdisciplinary 'centers of excellence.' If successful, these 'start-up' research units may evolve into larger and more permanent structures.

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[1] Through 2005, these included: Auburn University, Case Western University, George Washington University, Indiana University, Kansas State University, North Carolina State University, Ohio State University, Rutgers University, SUNY Stony Brook, University of California-Berkeley, University of Connecticut, University of Illinois at Urbana-Champaign, University of Iowa, University of Nebraska, University of Virginia, Vanderbilt University, Virginia Tech, Washington State University. Some programs are not exclusively dedicated to interdisciplinary programs.

The availability of federal center grants and large interdisciplinary awards is a clear external incentive for these programs. Federal center grants assure a revenue stream over several years and are usually regarded as prestigious. As center grant proposals tend to be elaborate and demand significant effort from investigators to build the scientific basis for long-term collaborations, universities have felt the need to provide support for faculty in pursuit of these major awards. Significantly, Ohio State University calls its funding scheme 'Large Interdisciplinary Grants Development Program.' To compete for seed funding, faculty members must commit to apply for federal awards of a certain dollar amount.

Duke University tied central allocations to interdisciplinary units to its strategic planning cycle in 2000–2001. Centers receive central funding over a delimited time-period, and undergo 5-year reviews whose default outcome is termination. A faculty member who directs an inter-school unit that has received central funding explains the expectations:

> They [the administration] view this as seed money, and they'll view how the [X] center succeeds in the review format by how much grant money we bring back in. That would be one of the metrics… if a working group produces a Science or Nature paper, that matters too… but they're looking for more than just a peer-reviewed article that's interdisciplinary. They want something more substantive than that…. I think the expectation also is that they want us to go out and try for bigger grants in different fields, you know, million-dollar plus grants… they're not going through all this so that someone can write a 250,000 dollar grant. I can do that on my own, I don't need a center's help. They want to change the makeup of research on campus. So they produce 10 or 20 of these centers and some of them will be cut off and some of them will continue, depending on their success, which I think is fair.

While central seed funding is not new, the convergence among universities in the rationalization of this practice in formal, systematic programs is illustrative of the contemporary trend towards the rationalization of university management and budgeting processes (Rhoades 2000). The centralized schemes to fund new inter-departmental collaborations resemble in part the provision of 'venture capital' for entrepreneurs to initiate (risky) new firms. As venture capitalists, university administrations hope that researchers succeed in generating their own revenues, from which the campus can ultimately benefit through indirect cost recoveries on external awards, purchased research equipment added to the overall infrastructure, and the visibility of the unit's scientific program. Interdisciplinary groups supported through these mechanisms are expected to behave as 'quasi-firms' (Etzkowitz 2003), actively seeking external sources of support. This is not fundamentally different from the usual behavior of research groups in general, or interdisciplinary ORUs in particular. The interesting nuance of these arrangements is on the valuation posed on the establishment of inter-departmental and inter-college collaborations. Such valuation may reflect an increased emphasis on such forms of cooperative research by federal agencies, although it is unclear what exact proportion of programs from which agencies actually enforce such requirements. These seed funding schemes also suggest that small interdisciplinary structures are not necessarily initiated from the 'bottom up,' as previously suggested (see Table 1): senior administrators have provided the incentives for small interdisciplinary 'start ups' to form.

Steering structures

At the other hand of the spectrum, universities have established interdisciplinary research units that do not conform easily to previous classifications such as 'large academic

Table 1 Interdisciplinary research structures

Small academic (<10 Persons)	Bottom-up initiation
	Research is primary; training is byproduct
	Loose management structure
	Many participants have disciplinary research commitments as well
Large academic	Bottom-up initiation, top-down incubation and management
	Research and training components
	Management by directors who report directly to vice president for research or equivalent
	Tend to be permanent features: new building, instrumentation
	Some centers ''co-hire'' faculty, but faculty are affiliated with departments
	Space allocation: mix of permanent and ''hotel'' facilities

Source: National Academies (2005)

structures,' although they share some of the characteristics listed in Table 1. These 'campus-wide' institutes are in effect 'steering structures' that oversee and coordinate resources in broad segments of the university, encompassing a multitude of academic units. They 'steer' institutional investments towards core facilities—research infrastructure and services shared by faculty in a number of departments, often containing laboratory space for multidisciplinary collaborations.[2] As science becomes increasingly expensive, such facilities are an efficient way to rationalize institutional resources amid constant competitive pressure to enhance the research enterprise. Campus-wide institutes also 'steer' faculty recruitment and time allocation towards certain areas and modes of research identified with their interdisciplinary mandates, although their ability to do so relates to the resources they control. Penn State and Stanford provide illustrative examples.

Penn State established four such institutes in materials research, environment, social sciences and life sciences between the mid-1990s and the early 2000s. The administration enacted compulsory cost reductions in the academic units in the mid-1990s, pooling the savings into a fund to develop these strategic initiatives (see also AAU 2005). The largest unit is the Huck Institute for the Life Sciences, which has co-recruited around 60 faculty with several departments on campus and occupies a new research facility. The Penn State institutes were formed at the initiative of the central administration and are centrally funded to build research capacity in strategic areas for the university, through faculty co-hiring and facilities. Occasional gifts and grants, such as the donation that named the life sciences institute and a state appropriation to help build a new material science building, have been supplementary to the internal budget.

Penn State administrators implemented the current model of interdisciplinary institutes in response to the university's previous experience with the 'Inter-college Research Programs,' units that were separately budgeted and expected to raise their own revenues. In the new model, the institutes are entirely funded by the administration and are not expected to generate grant income. External awards are administered through the academic units, to avoid competition between interdisciplinary units on one hand, and colleges and departments on the other: ''While there is fundamental recognition for the value of interdisciplinary research and collaboration, units have historically competed for credit and the resources that credit yield, and for real or perceived reputation'' (Pennsylvania State

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[2] For examples of new interdisciplinary research facilities, see Sá (2007).

University 2002, p. 35). The function of the institutes is therefore to rationalize the use of resources (e.g., research facilities, equipment) and make targeted investments to enhance the research enterprise, through faculty co-funding and planning grants.

At Stanford, similar units in the health sciences, environmental studies, and international studies emerged from the bottom up and have become staples of the university's commitment to interdisciplinary research and advanced training. Stanford relies heavily on fundraising to build its institutes, although some central funds have been used for programmatic activities. Indeed, they are a key element of Stanford's $4.3 billion fundraising campaign launched in late 2006. Of the total fundraising target, $1 billion is targeted to the three initiatives.[3] Bio-X, the campus-wide institute in health sciences, is the most developed unit. It occupies a modern new facility—the Clark Center—built with around $150 million in gifts. The center houses about 35 faculty from multiple departments, arranged in contiguous laboratory spaces along interdisciplinary themes. A university official views the goal of Bio-X/Clark Center as to ''to change the way people do and view science.''

Faculty are also appointed in academic units, and research grants are managed through the schools and departments. These initiatives, as Penn State's institutes, are established to provide a single and visible face for decentralized scientific expertise on campus that is not captured by traditional departmental divisions (e.g., 'environmental research'). Such visibility is regarded as an important factor in the external recognition and appraisal of the university's research strengths. Control over a research facility enhances internal visibility and helps attract faculty, as is often the case with ORUs (Ikenberry and Friedman 1972; Mallon 2006). Nevertheless, these units are often intended to have porous boundaries, allowing a large number of researchers to participate.

Campus leaders (e.g., upper administrators, senior faculty, deans) make strategic decisions about the direction of growth of the research enterprise as they create and support these units, effectively steering the course of institutional development. It does not follow that such direction is necessarily at odds with faculty governance and the traditional disciplinary structure. Faculty may have strong participation in the initiation of these units, and inter-school committees composed by professors and college deans can participate in the institute's academic policy-making and governance. Informal channels of power and influence are also reportedly used to circulate ideas among faculty and administrators.

Models of faculty recruitment and evaluation

A few universities have changed policies and practices in key areas such as faculty recruitment and evaluation to accommodate researchers with interdisciplinary interests. These strategies are noteworthy for changing institutionalized norms that are central to the academic operation, always a difficult and sensitive task.

Duke University and the University of Southern California have reformed their faculty promotion, evaluation and recognition policies to account for interdisciplinary interests. Both institutions now require colleges and schools to accommodate the interdisciplinary work of faculty in the evaluation, promotion, and tenure processes.[4] At Duke, about a year of discussions preceded the new policy, which requires the administrators of academic units to appoint experts from outside the department or school to participate in and co-chair

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[3] See http://thestanfordchallenge.stanford.edu/get/layout/tsc/TheStanfordChallenge? indexredir=r

[4] See University of Southern California (2005), and Duke University (2004).

tenure review committees in cases of faculty with interdisciplinary interests. This long process was devised not only to obtain buy-in, but also to instill cultural change, as explained by a senior administrator:

> … we vetted it at meetings of all the department chairs of the interested schools, we brought it to the dean's cabinet, we brought it to the advisory council of the academic council, we brought it to the full academic council, and took it to the board of trustee. I don't know that it needed to take that long, but it felt like it was so significant that we wanted everyone to hear about it and everyone to feel like they had had participation in doing it. In other words, part of the process of taking it around all those committees was changing the culture…. At the time that the vote came, it was a unanimous vote, as opposed to something divisive.

Duke is particularly noteworthy in the scale and scope of its efforts to remove structural obstacles to inter-departmental collaborations, create incentives for such activities, and instill a favorable culture to interdisciplinarity.[5] The university seems to count on the leadership necessary to implement a 'steady state of change' (Clark, 2004) regarding interdisciplinarity.

The University of Wisconsin-Madison implemented in the late 1990s the Cluster Hiring Initiative, as a response to the state budget cuts that caused severe faculty attrition (c. 250 positions). The university successfully raised state and private matching funds (c. $15 million) to support new hires into interdisciplinary 'clusters' of up to 5 researchers, proposed by the faculty and selected competitively. Five rounds of competitions took place between 1997 and 2001, whereby about 140 faculty members were recruited into 49 clusters. Inter-deparmental search committees recruit individuals into the cluster, and then identify an adequate department to be the academic home of the faculty member. The cluster positions are fully funded and 'owned' by the central administration, but faculty for all purposes belong in the assigned department. The 'cluster' itself is a virtual entity that is not part of any governance or organizational framework, and faculty members are free to shape their activities as they wish. As one senior administrator explains:

> If people are going to be successful you have to respect how they operate in their own cultures. You can't force a one size fits all structure on how clusters ought to be organized, and how they ought to be administered. We sort of let them do their own thing, and then try to get some handle on whether this is working or a disaster, a waste of $15 million. I don't think even in the worst circumstances this would be a waste, I think what would happen is that people would spring back into the standard faculty model, and we'd end up with 150 new faculty looking like the other faculty.

UW-Madison has set up a 'natural experiment' with the clusters, and has attempted to take hold of their experience through internal assessments (University of Wisconsin-Madison 2003, 2007) and conferences.

'Cluster hiring' has since been announced and implemented in other institutions. Rensselaer Polytechnic Institute is forming a few faculty 'constellations' funded through private gifts. RPI's constellations are focused on the priority research areas of the institutional strategic plan, emphasizing technological areas with potential for economically relevant discoveries. Florida State University has recently announced a 200-faculty 'cluster

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[5] For a detailed case study, see Sá (2006). Others have also cited Duke as an example in this regard (Feller 2004; Brint 2005).

hiring initiative' in 2006, following the Wisconsin's model, but creating clusters of 5–8 members. Louisiana State University is also in the process of establishing 2–4 clusters of 5–8 faculty members (2006/2007) following the Wisconsin model. In all these cases, the clusters are framed as a mechanism to attract distinguished researchers and create 'peaks of excellence.'

A different approach has been taken at the Penn State through the institutes described above, which manage a faculty co-funding scheme. Institutes support half the cost of a new faculty position proposed by a department, on the condition that the position will contribute to fostering inter-college collaborations. This is different from the dual-appointment of faculty to a research center and a department, which may have different physical locations and disparate research agendas. As departments initiate the positions, they have to align the goals for the new hire with the institutes' mandate, but faculty remain for all purposes housed within the department. The institutes review co-funded positions periodically to assess the continuity of co-funding, in relation to the established goals for the positions. The four institutes have co-funded about 150 faculty members.

These hiring models generated controversy (to different degrees) on their campuses, as faculty recruitment is usually understood as a departmental prerogative. Preliminary internal assessments of UW-Madison's cluster faculty and Penn State's co-funded faculty employ research productivity data to assess their efforts.[6] At UW-Madison, cluster faculty have reported the usual perceptions of interdisciplinary work being undervalued at the time of evaluation and promotion (University of Wisconsin-Madison 2003, 2007). At Penn State, the process of academic evaluation for promotion and tenure purposes and the institute review of the co-funding arrangement are regarded as separate, and the latter is not supposed to influence the former. The practical implications of these models will become clearer as universities learn more about faculty experiences hired through new means and evaluated under revised guidelines. A sense of experimentation is shared among administrators and faculty involved in these new strategies.

Discussion

This paper sought to identify and analyze emerging organizational strategies to foster interdisciplinary research, and consider their implications. Above, three 'generic' approaches were considering, subsuming comparable and yet diverse strategies of several campuses. The first two approaches concern interdisciplinary ORUs, and the third concerns changes in the core policies and practices of faculty recruitment and evaluation. This section considers implications and suggestions for further research.

University efforts to nurture interdisciplinary research teams and centers attempt to reduce the transaction costs of such work. Incentive grants address the long noted funding gap for these activities ('orphans in the fiscal structure of the university,' see Feller 2002). They provide, as an academic administrator suggests, 'a reason for faculty to get out of their labs' and engage with colleagues from other disciplines. The financial incentives provided help offset the costs of necessary inputs, such as faculty time, research and administrative support, and materials and equipment, all of which might not be available otherwise. Such incentives are clearly important as scientific research is increasingly costly

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[6] UW-Madison's reports also employ descriptions of the research activities of some clusters to portray their achievements. For Penn State's, see Pennsylvania State University (2005).

(Ehrenberg et al. 2003), and they may indeed motivate faculty to pursue innovative ideas (Powers 2000).

Conspicuously missing, however, are critical appraisals and assessments of the short- and long-term outcomes of the use of institutional funds as 'seed money.' Considering the rationalizing trend driving the adoption of such incentive mechanisms, it would be expected that universities attempt to develop more systematic ways of gauging their effectiveness. While administrators usually view them positively and regard them as effective, the evidence presented to substantiate these claims is largely anecdotal (e.g., examples of groups that obtained major grants). If the use of institutional grants by incumbent groups or centers is considered valuable in and of itself, that is not a major concern. But as 'investments' in the quality and mode of research carried out on campus, the experience of universities with such programs can be examined more systematically. For example, do university officials consider the returns on the investment of these programs vis-à-vis opportunity costs? What are some acceptable parameters to determine the success or relative effectiveness of institutional incentive grants? What are (and should be) the relative weighs of productivity measures of success and qualitative gains in the nature of the science performed? Investigation of a number of such funding schemes across campuses could help illuminate these questions. Some studies suggest that targeted institutional investments oftentimes generate unintended consequences, including declines in the morale among the faculty whose proposals are not funded (Rhoades 2000; Powers 2000). Comparative studies might elucidate the mechanisms that heighten or minimize such consequences.

It seems clear that episodic financial incentives are important but not sufficient to cause lasting change. As one senior administrator notes, ''so much of success in interdisciplinarity is a cultural issue, and an incentives issue, and it's both. The incentives by themselves will not succeed.'' In spite of recurrent observations about the importance of culture and climate (Feller 2002; Lattuca 2001), the relative hospitability of different campus cultures to interdisciplinary work, as well as the means through which such cultures get established or changed, remain by and large unexplored (but see Hollingsworth and Hollingsworth 2000). Further work is also needed to refine our understanding of the specific aspects of campus cultures that influence faculty research behaviors.

Some universities have taken steps to extend the degree to which they operate in matrix-like arrangements. The organizational image of a matrix structure serves as an explicit metaphor of how the university operates or should operate for several administrators and faculty interviewed (see also Roberts 2004). Campus-wide institutes stand orthogonally to the traditional academic structure, drawing on the faculty from departments for crosscutting projects, catalyzing collaborations through the provision of workspace and planning grants, influencing university investments in core facilities, and participating in faculty recruitment along with departments. These and other interdisciplinary ORUs can be viewed as 'project units' in a university matrix, which focus part of institutional resources and energies on boundary-crossing areas of research. For all the use of the matrix metaphor in the higher education literature and policy reports (Alpert 1985; National Academies 2005; Roberts 2004), research that examines the operation of ORUs in light of studies of matrix management in other types of organizations (Gailbraith 1971, 1972; Davies and Lawrence 1977; Kolodny 1979; Larson and Gobeli 1987; Burns 1989) are missing. This is particularly surprising, given the similarities in the issues raised in studies of ORUs and matrix structures. Such issues include power and priority disputes between the 'project' and the 'functional' units, confusing reporting relationships, tensions over resource allocation, and uncertainty about handling the continuity or termination of project units.

Indeed, much empirical research remains to be done to enlarge our understanding of interdisciplinary ORUs. The roles of different funding models, modes of coordination, managerial styles, and incentive structures in shaping the outcomes of such units remain poorly understood (Mallon 2006).

Based on this and previous studies, one can hypothesize that the more these campus-wide institutes compete, or are perceived to compete with colleges and schools for resources (e.g., operating budget, programmatic funding, infrastructure), the more likely are deans and academic administrators to antagonize these units. Conversely, more cooperation tends to occur if these ORUs are viewed as generating additional resources to the academic units and helping them enhance their research roles. In the examples provided above, the universities attempted to avoid dynamics of competition and emphasized the integration of the boundary-crossing and academic units. This was done primarily through central funding for the former, eliminating the need for them to compete with the latter for priority over faculty time and credit in external research grants. In both cases, there is also involvement from the colleges and schools in the governance of the institutes, in order to increase consensus over the overall research direction of such units. The 'business model' of campus-wide institutes is different from the usual generalization of ORUs as revenue-seeking units (Ikenberry and Friedman 1972; Stahler and Tash 1994; Mallon and Bunton 2005).

Given the deep roots of traditional academic structures, the small number of institutions that engage in the reform of core academic policies and organizational frameworks is to be expected. In scale, the recruitment models examined still innovate at the margin, responding for a relatively small fraction of faculty hiring. They build upon existing policies and practices in evolutionary ways, rather than represent 'radical innovations.' They do introduce new terms in the vocabulary of university models, however, which might sound foreign to critics in the Veblenian tradition and intuitive to enthusiasts of strategic change and innovation in academia. To reform campus policies to facilitate interdisciplinarity, as exemplified by promotion and tenure procedures that are recognized as salient obstacles (National Academies 2005), the greatest effort for campus actors seems to lie in conceiving of such change as legitimate and desirable. Studies that compare the experience and trajectories of faculty on campuses with widely different norms regarding the evaluation of interdisciplinary research could determine the effects of such arrangements.

Finally, future work that allies the richness of ethnographic studies of faculty involved in interdisciplinarity (e.g., Lattuca 2001) to identifiable organizational conditions would be an invaluable addition to the knowledge base. Reports of organizational units considered successful (National Academies 2005; AAU 2005; Klein 1990) often lack a more detailed examination of the actual experience of researchers, raising questions about how consensus emerges regarding their 'success.'

Concluding remarks

The strategies discussed here expand the repertoire of organizational arrangements in research universities, some in subtle, others in substantive ways. Incentive grants, steering structures, and new models of faculty recruitment and evaluation create organizational conditions that are expected to contribute to the practice of interdisciplinary research. It is important to note that correlates to these strategies may and do also take place at lower organizational levels, i.e., divisions, colleges, and departments. But the focus here has been on examining strategies at the institutional level, involving the central administration.

Proposals for radical transformation of universities to facilitate interdisciplinarity, based on the belief in its inevitability and desirability, and on a view of the disciplinary-departmental model as a source of constraint for the advancement of knowledge, are not likely to have a meaningful impact on U.S. research-intensive institutions in the near future. The ability to accommodate multiple and competing demands for knowledge production through increasingly complex, layered, and intersecting organizational arrangements over several generations is a central feature of the U.S. university model, which preserves at its core the nexus between disciplines and departments. More probable is the continuing experimentation with strategies that are perceived to address relevant, context-specific organizational problems and aspirations; such strategies ultimately help enhance the research enterprise, generate external support and funding, augment institutional prestige, and attract and retain talent. It is through those means of 'validation' that new organizational structures, policies, and practices are likely to take root on campuses, and not through appeals to broad shifts in knowledge production.

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