4

The Academic Researcher and Interdisciplinary Research

Individual researchers involved in interdisciplinary research (IDR) require a supportive environment that permits them to work in multiple disciplines and departments and to be fairly evaluated and rewarded for both their interdisciplinary and their disciplinary work. They have a responsibility to explain and demonstrate the benefits of IDR, venture into new fields, and be open to the cultures and values of other disciplines.

The following sections condense numerous interviews, workshop discussions, survey results, and firsthand experiences of committee members to portray in some depth the experiences of interdisciplinary students, postdoctoral fellows, and faculty members in academic institutions. Much of this material is based on anecdotal evidence, complemented by a large number of case studies and other reports in the literature, but its origin in experience can be instrumental in understanding the importance of providing IDR-friendly environments at every stage of a scientific career.

Researchers need opportunities to train in two or more disciplines and to work closely with faculty members and students in each. Such cultural and intellectual immersion is a prerequisite to high-quality interdisciplinary work. Researchers may need to spend considerable time on activities (teaching, research, committees, and community service) outside their home department. In the committee's survey of those interested in IDR, over half indicated that after training in a specific field they had sought training in additional fields through either postdoctoral fellowships, further advanced

degrees, or day-to-day interactions in interdisciplinary projects. People whose home departments do not recognize, encourage, and reward such activities may not be willing to make the extra effort required for interdisciplinary activities.

Convocation Quote

The most interesting observation is that the students are the integrating glue. Graduate students, undergraduates, and postdocs are the ones that go between the laboratories that make things happen.

Harvey Cohen, professor of pediatrics, Stanford School of Medicine and chair, Interdisciplinary Initiatives Program

UNDERGRADUATES

Undergraduates can have a rich educational experience when they learn about and in more than one discipline, especially when education is complemented by research experience. Students at Brown University have shown a consistent interest in interdisciplinary programs (Figure 4-1). At Columbia University the number of students majoring in interdepartmental or interdisciplinary programs has increased dramatically over the last 10 years (Figure 4-2). Harvard University students are also increasingly interested in interdisciplinary studies: the number of undergraduate joint concentrations in chemistry and physics has risen from 14 to 45 over the last 15 years (see Box 9-2). At Stanford University a multiyear decline in the number of students majoring in earth science was reversed when the major, originally based in the single discipline of geology, was reformulated into the interdisciplinary program "earth systems" (see Figure 8-1).

University policies can facilitate or hinder students' ability to learn about IDR and to take double majors, take courses in other schools, or custom-design their majors and participate in IDR. For undergraduates to gain deep interdisciplinary insights, they need to work with faculty members who offer expertise both in their home disciplines and in the interdisciplinary process (see Box 4-1). In the committee's survey, the top recommendations to students were to cross boundaries between disciplines (25 percent), to take a broad range of courses (23.4 percent), but also to develop a solid background in one discipline (12.3 percent). Respondents overwhelmingly recommended that educators incorporate interdisciplinary concepts in course curricula (Figure 4-3). But structural roadblocks can impede faculty in offering the team teaching and co-mentoring that are essential to undergraduate education. Another barrier in some disciplines,

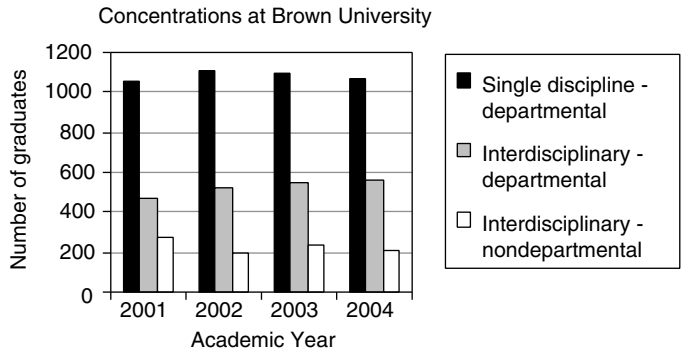

FIGURE 4-1 Consistent undergraduate interest in interdisciplinary studies at Brown University.
NOTES: In consultation with an appropriate faculty member, students at Brown University devise a concentration program centered on a discipline or disciplines, problem or theme, or broad question; they may also select a standard departmental concentration. Interdepartmental concentrations make up about one-third of the standard programs. Students may also design their own concentration, in which case a written proposal presenting a statement of the major objectives of the concentration program and a list of the specific courses to be taken are signed jointly by the student and faculty adviser and submitted to the College Curriculum Council for approval. Standard concentration programs require only the approval of the appropriate department or committee. In this environment, consistently over 40 percent of students graduate with an interdisciplinary concentration, 30 percent from departmental and 10 percent from non-departmental programs.
SOURCES: Data provided by the Office of the Dean of the College, Brown University, June, 2004, Brown University Undergraduate Concentration Requirement: General Information *http://www.brown.edu/Administration/Registrar/concentration. html*; Brown University Dean of the College, Academic Advising and Support, Concentration Programs *http://www.brown.edu/Administration/Dean_of_the_ College/DOC/s1_advising_support/conc_codes.shtml.*

such as engineering, is a curriculum so packed with required courses that it is difficult to take electives or concentrations in disciplines outside the major.

GRADUATE STUDENTS

Many researchers begin serious involvement in IDR as graduate students. They may obtain a master's degree in a second subject; for example,

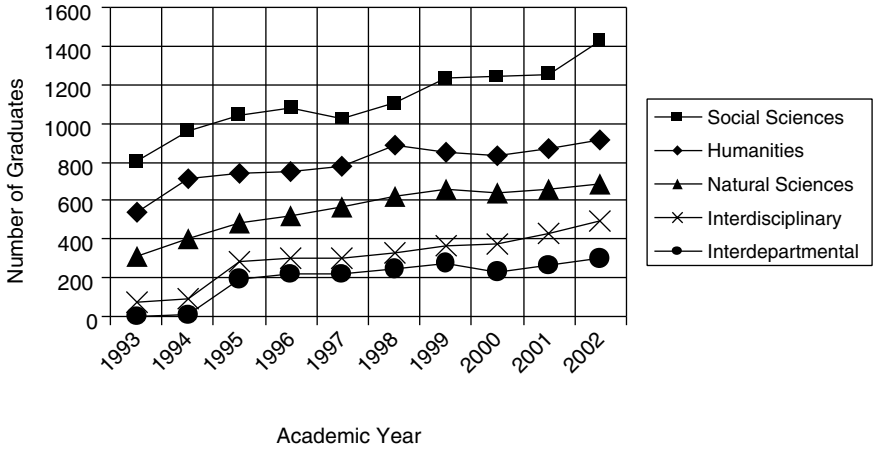

FIGURE 4-2 Trends in undergraduate interest in interdisciplinary studies at Columbia University.
NOTES: There has been a marked increase in the number of undergraduates at Columbia graduating with interdisciplinary or interdepartmental majors or concentrations. This increased student interest followed university administration promotion of and faculty interest in interdisciplinary research and teaching in the 1990s. The 9.7 percent average annual increase in interdisciplinary program majors and concentrations has outpaced interdepartmental (6.7 percent), and departmental majors and concentrations (4.8 percent).
SOURCE: Data provided by the Office of the Vice President for the Arts and Sciences, Columbia University, May 2004; average annual increase was calculated for the years 1995-2002 and does not include the very large increase in majors and concentrates in interdisciplinary and interdepartmental programs that occurred between 1993-1995.

economics or psychology majors may take an MS in statistics to deepen their understanding of statistical analysis. Such involvement depends on finding multiple advisers who are interested in working together and with the students; on gaining sufficient training in the "other" discipline, which calls for the support of the home department. For doctoral students working in an IDR team environment, fulfilling the requirements for a PhD qualifying examination or dissertation in the home department may require extra planning and coordination between departments (see Box 4-2). There may be barriers to entry, such as admissions policies, that are biased against students whose undergraduate degree is not in the same discipline as the proposed graduate degree.

TOOLKIT

BOX 4-1 IDR Immersion Experiences: Summer Research Opportunities

One of the common themes that runs through any discussion of interdisciplinary interactions is the learning of new disciplinary languages and cultures. One way to accomplish that is to immerse oneself in a new discipline. There are several examples of immersion research experiences; most tend to be summer internships. All feature an infrastructure and an informal, interactive scientific community that allows researchers to launch into research almost immediately upon their arrival and to develop long-lasting research networks and collaborations.

The Berkeley Mathematical Sciences Research Institute (MSRI)[a] offers postdoctoral scholarships in conjunction with Hewlett Packard and Microsoft Research. MSRI postdoctoral fellows are in residence for 5 months. Microsoft Research has an inhouse internship program[b] for research on human-computer interactions.

Woods Hole Marine Biological Laboratory offers a visitors program[c] in which summer researchers—graduate students and postdoctoral scholars and professors—enjoy 3 months of research without academic responsibilities. In 2003, 139 principal investigators and 201 other researchers from 144 institutions in 18 countries converged on MBL to perform research in marine biology, neuroscience, and ecosystems.

The Shingobee Headwaters Aquatic Ecosystems Project (SHAEP)[d] in Minnesota offers summer interdisciplinary immersion experiences for researchers interested in hydrology. Developed in 1987 around instrumentation installed and funded by US Geological Survey researchers, SHAEP is based on the concept that proper management of water resources requires knowledge about atmospheric water, surface water, groundwater, and how these resources function as an integrated system. There are no dedicated faculty members, but a full-time staff coordinator was only recently hired. People using the site share equipment but must bring their own funding. There are no constraints on the number of people participating or on their disciplines. SHAEP has instrumented similar interdisciplinary sites in Nebraska, North Dakota, and New Hampshire.[e]

Yet another summer interdisciplinary immersion experience can be had at the University of Michigan's Biological Research Station (UMBS). At any given time, there are usually 250 people present, a mix of resident researchers and short-term researchers. The site was developed by biologists, but atmospheric scientists recognized that the instrumentation available was also useful for their research. Weekly talks were initiated, and the two groups forged an understanding on research terminology, methodology, and the measurements that each group was capable of taking. The talks inspired the Biosphere Atmosphere Research and Training (BART) and Integrative Graduate Education and Research Traineeship (IGERT) program, a multidisciplinary doctoral training program.[f] During two summers at UMBS, BART students from over 15 universities participate in educational research programs at the biosphere-atmosphere interface.

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[a] *http://www.msri.org/.*
[b] *http://research.microsoft.com/aboutmsr/jobs/internships/.*
[c] *http://www.mbl.edu/research/summer/index.html.*
[d] *http://wwwbrr.cr.usgs.gov/projects/SHAEP/index.html.*
[e] *http://www.npwrc.usgs.gov/clsa/index.htm.*
[f] *http://www.bart-wmich.org/.*

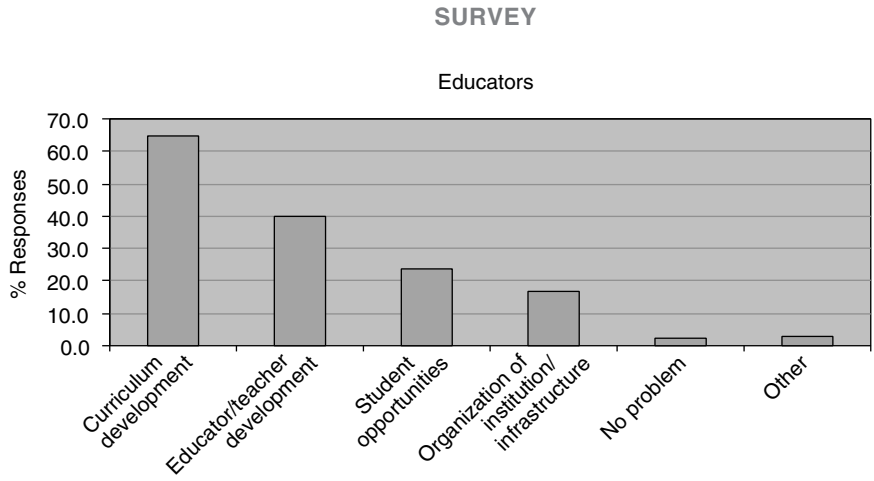

FIGURE 4-3 Recommendations to educators.
NOTES: Survey Question: If you could recommend one action that educators could take that would best facilitate interdisciplinary research, what action would that be? Survey respondents (n = 190) recommended that educators develop curricula that incorporate interdisciplinary concepts (64.7 percent), take part in teacher-development courses on interdisciplinary topics (40 percent), and provide student opportunities in IDR (23.7 percent). These recommendations echo other recent reports and statements.
SOURCES: Gregorian, V. 2004, "Colleges must Reconstruct the Unity of Knowledge" The Chronicle Review, Vol. 50/39, p. B12; Kellogg Commission, "Renewing the Covenant: Learning, Discovery, and Engagement in a New Age and Different World," March 2000, *www.nasulgc.org/publications/Kellogg/Kellogg 2000-covenant.pdf*; Bartlect, T. 2004, "What's Wrong with Harvard?" *The Chronicle of Higher Education,* Vol. 50/35. p. A14.

The last step may be hindered when examiners view a student's work from the viewpoint of only a single discipline. One study concludes that although graduate students report that interdisciplinary activities have adverse effects on their careers, they are convinced of the value of IDR; the study also describes graduate students and postdoctoral scholars as "essential links" in the skill networks of IDR centers.[1]

[1]Rhoten, D. Final Report, National Science Foundation BCS-0129573: A Multi-Method Analysis of the Social and Technical Conditions for Interdisciplinary Collaboration. September 29, 2003. Available at: *http://www.hybridvigor.net/interdis/pubs/hv_pub_interdis-2003.09.29.pdf*.

INNOVATIVE PRACTICE

BOX 4-2 Interdisciplinary Departments Train Interdisciplinary Students

The School of Life Sciences (SOLS) at Arizona State University (ASU) has taken a directed approach to changing the culture of the unit and in the process has affected how graduate students are being educated. Within SOLS, discipline-based and interdisciplinary researchers are developing a culture that supports both disciplinary and interdisciplinary approaches to research.

The school has 80-85 faculty members who are organized into six faculties that have few fixed boundaries. The six faculties have no budget lines, and each year members are allowed to move freely among them. Among the faculty members are historians of science, bioethicists, policymakers, and philosophers of science. Faculty members in the humanities and social sciences are imbedded in the department, and this allows a truly interdisciplinary educational experience that includes such concentrations as "Biology and Society" and such research groups as "Human Dimensions of Biology."

Students in ASU's urban-ecology IGERT write one chapter of their dissertation jointly with a student who is also in the program but in another department. Coauthorship, one obstacle to IDR, would be easier to overcome if researchers were involved in such collaborations during their training. Students conducting IDR also benefit greatly from the guidance of mentors in the several disciplines represented. Comentoring allows students to have direct relationships with researchers in the different fields while synthesizing the training and advice to form their own skills and experiences for their future IDR goals.

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[a]James Collins. Convocation on Facilitating Interdisciplinary Research. Washington, DC, January 30, 2004.

POSTDOCTORAL SCHOLARS

A postdoctoral experience often provides the best opportunity for researchers to train deeply in a new discipline. The training provided in postdoctoral years can provide skills and knowledge beyond those acquired by graduate students, which are focused on the home discipline. Respondents to the committee's survey encouraged postdoctoral scholars to broaden their skills and knowledge base (see Figure 4-4). Despite committee interviews that indicate heightened interest in IDR among postdoctoral scholars, progress toward interdisciplinary expertise may be slowed by a relative shortage of interdisciplinary postdoctoral fellowships. Moreover, a potential fellow may not be sufficiently knowledgeable about the secondary discipline to be useful to a potential mentor.

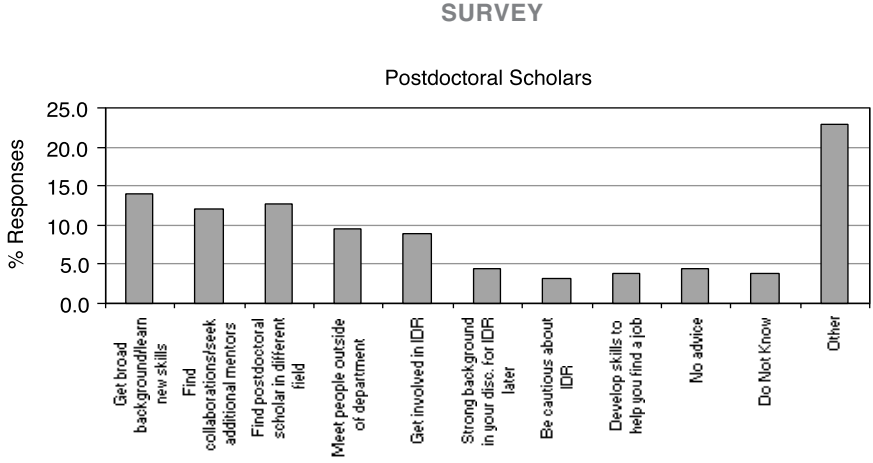
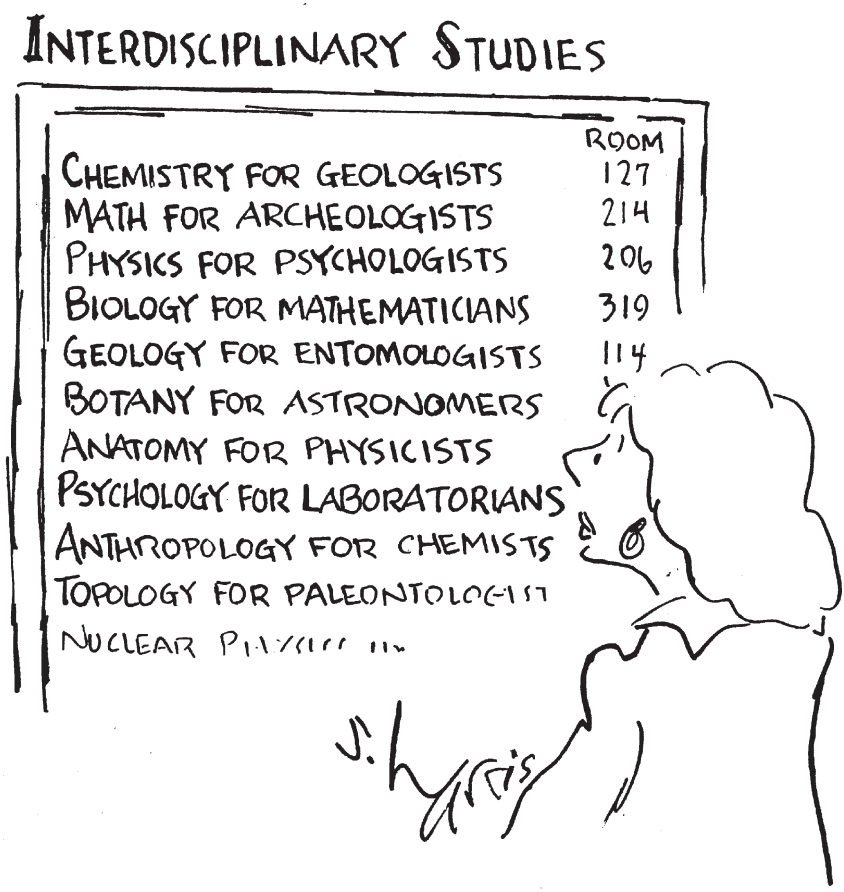


FIGURE 4-4 Recommendations for postdoctoral scholars.
NOTES: Survey Question: If you could recommend one action that postdoctoral scholars could take that would best facilitate interdisciplinary research, what action would that be? Respondents (n = 157) encouraged postdoctoral scholars to get a broad background and learn new skills (14.0 percent), to find postdoctoral fellowships in fields different from their own graduate work (12.7 percent), and to develop collaborations and seek additional mentors (12.1 percent). A recent report listed similar recommendations.
SOURCE: NRC, "Enhancing the Postdoctoral Experience for Scientists and Engineers," National Academy Press, 2000.

A productive transition from graduate student in one department to postdoctoral fellow in another frequently requires "translators" who can provide training in the postdoctoral environment. Such trainers need to be well enough versed in both disciplines (and in their methodological and knowledge differences) to simultaneously help the postdoctoral scholars obtain new skills and knowledge and share perspective about research issues (see Boxes 4-3 and 4-4).

A special challenge for all postdoctoral researchers, whether disciplinary or interdisciplinary, is to produce an expected number of publications and other indicators of productivity. The additional training in a new field needed for an interdisciplinary researcher may reduce a postdoctoral scholar's apparent productivity relative to that of a scholar who focuses on a single discipline. As a result of the lower productivity, they may require more time and assistance in finding faculty positions after the postdoctoral



period, although postdoctoral scholars interested in pursuing nonacademic careers may find their employability enhanced by their interdisciplinary experiences.

HIRING

Candidates for tenure-track positions who are interested in IDR face the additional challenge of finding departments that feel that the candidates "belong" with them. Universities vary in their willingness to offer joint positions; for example, the mathematics department at Stanford University does, but the physics department does not. When asked whether their

institution made joint appointments in which salary support was shared between hiring units, 58 percent of respondents to the committee's individuals survey and 63 percent of respondents to the provosts' survey said yes. More than 75 percent said that 0-10 percent of faculty members held joint appointments.

Although joint appointments may be the only recourse for some, these researchers may find themselves serving two masters and satisfying neither. For example, universities may become concerned when a faculty candidate's annual research productivity has been lower than that expected of single-discipline candidates. Some universities and research supervisors offer mentoring and active assistance in helping departments to assess the value and substance of the work of IDR candidates.

INNOVATIVE PRACTICE

BOX 4-3 The Global Environmental Assessment Project

The Global Environmental Assessment (GEA) Project,[a] based at Harvard's Kennedy School of Government, ran an interdisciplinary research and training program funded by a 5-year grant from the National Science Foundation. To help to build a next generation of professionals trained in and sensitive to the unique problems of linking science and policy on global environmental problems, the GEA Project recruited fellows through an international competition open to natural scientists, social scientists, and professional-school students. A unique aspect of the program was the commitment to generational change in the visibility and acceptability of IDR, by bringing together a "critical mass" of young scholars with the intent to foster interdisciplinary and international collaborations during this formative stage in their careers.

Fellows were exposed to interdisciplinary methodological and professional approaches and perspectives in the year-long training experience, which consisted of discussions of key papers from various intellectual perspectives, presentations of research by GEA faculty and visitors, and an introduction to the science and policy of the specific issues studied each year. During the first 2 months of fellows' residence, seminars introduced them to program faculty and provided an early opportunity to discover how different are the things "taken for granted" in conceptualizing and pursuing research. In November and December, fellows designed their research projects, which they then pursued in field research through March. Results were used as input to annual GEA Project workshops at which practitioners, users, and scholars of environmental assessment engaged in off-the-record discussion comparing insights and experiences. Fellows' papers were

Convocation Quote

Our students are marketable as civil engineers, hydrologists, forest ecosystem biologists, or fishery scientists. But they are very subversive in that they are trained in a very different way. So, you get a hydrologist, who knows not only what he or she is supposed to know in a civil engineering department, but a hydrologist who can deal with the climate dimension and who can connect it to the societal dimension.

Ed Miles, professor of Marine Studies and Public Affairs, University of Washington

posted on the GEA Project's public Web site, and the best of them have been revised for inclusion in the three volumes of final output from the project.[b]

The project graduated 37 fellows in 12 disciplines (anthropology, business and management, economics, engineering, environmental sciences, geography, law, oceanography, physics, political science and government, public policy, and science and technology studies) and of 10 nationalities (American, Australian, British, Bulgarian, Canadian, Danish, Dutch, German, Indian, and Swiss). There were 15 predoctoral fellows, 16 postdoctoral fellows, one practitioner, and five faculty fellows. All were readily able to get employment, and most US fellows have academic jobs (see table below). A network of alumni fellows is maintained to encourage continuing collaboration.

Current Jobs held by 37 Former GEA Project Fellows

	US	International	Total
Academe	19 (51%)	5 (14%)	24 (65%)
Research Institutes	1 (3%)	7 (19%)	8 (22%)
Government	2 (5%)	1 (3%)	3 (8%)
Unknown	0 (0%)	2 (5%)	2 (5%)
Total	22 (59%)	15 (41%)	37 (100%)

[a]The GEA Project Web page is *http://www.ksg.harvard.edu/gea.*

[b]Mitchell, R. B., Clark, W. C., Cash, D. W., and Alcock, F., eds. Forthcoming. *Global Environmental Assessments: Information, Institutions, and Influence*. Cambridge: MIT Press. Jasanoff, S., and Martello, M. L., eds. 2004. *Earthly Politics: Local and Global in Environmental Governance*. Cambridge: MIT Press. Farrell, A., and Jäger, J. eds. Forthcoming. *The Design of Environmental Assessments: Choices for Effective Processes*. Washington, D.C.: Resources for the Future.

INNOVATIVE PRACTICE

BOX 4-4 The Institute for Mathematics and Its Applications

The Institute for Mathematics and Its Applications (IMA) at the University of Minnesota was founded in 1982 with a grant from the National Science Foundation.[a] Its primary mission is to increase the impact of mathematics by fostering IDR. IMA's postdoctoral program was created to provide opportunities for mathematical scientists near the beginning of their careers who have a background or an interest in research involving applications of mathematics (e.g., mathematics of materials, genomics, networks, and financial engineering). IMA postdoctoral fellowships run 1-2 years and provide an annual salary of $45,000 and a travel allowance. There have been 191 postdoctoral members since IMA was founded in 1990 and 35 additional scholars in the IMA industrial postdoctoral program.[b]

IMA focuses on two important factors to ensure that postdoctoral scholars have a positive experience. First, it creates a focused scientific atmosphere built around a yearly thematic program in which one broad field of quantitative interdisciplinary science is studied; this offers a unique environment for the postdoctoral scholar to become truly immersed in a problem or question. Second, it dedicates a great deal of time to the mentoring of its postdoctoral scholars, involving both long-term visitors and local faculty members in mentoring roles. The industrial postdoctoral program offers recent mathematics PhDs the opportunity to work half-time in an industrial research laboratory while performing academic work. Postdoctoral scholars in this program receive mentoring from both industrial and academic coworkers.

In a continuing effort to evaluate, document, and improve its program, IMA collects followup information from its postdoctoral scholars in the form of surveys and requests for reports. For example, in spring 2003, IMA surveyed postdoctoral scholars from 2000-2001. On a scale of 1 to 5, 12 of the 13 responded with an average of 4.5 to the question, "Was your research more interdisciplinary because of the IMA?" They also agreed strongly with the statements "Interaction and collaboration were well facilitated by the IMA" and "I made useful contacts at the IMA."[c]

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[a]IMA home page: *http://www.ima.umn.edu/*.

[b]Complete lists of the IMA postdoctoral members and IMA industrial postdoctoral scholars with current affiliations can be found at *http://www.ima.umn.edu/people/all-reg-postdocs.html* and *http://www.ima.umn.edu/people/all-ind-postdocs.html*.

[c]Douglas N. Arnold, Director, IMA. Personal communication, March 26, 2004.

JUNIOR FACULTY

Many universities and departments appreciate the value of IDR but expect interdisciplinary faculty members to do "double duty": to first meet the usual obligations of disciplinary and departmental activity—including publications, teaching, and service—and then find additional time for IDR. Some junior faculty members achieve this by doing their interdisciplinary

work in a disciplinary way, such as publishing mathematical results related to their field in a mathematics journal rather than in a journal in their field; others fortify their credentials by doing purely disciplinary research that is not related to their interdisciplinary interest.

Faculty members also feel pressure with regard to activities outside their departments. For example, interdisciplinary teaching, especially at the graduate level, often involves activities that are not recognized or rewarded by the home department, including

- Service and committee work.
- Teaching courses with other faculty members.
- Teaching courses in other departments.
- Teaching courses to attract and train doctoral students in the faculty members' own fields of research.

Such activities may be considered "extra" and earn little or no credit. In addition, faculty members might not be permitted to advise graduate students in other departments even if they would be the most appropriate mentors. Similarly, coadvising students, which is often the best way to train in IDR (see Box 4-5), can be difficult or discouraged by the institution. These pressures can affect student advisees and thus faculty members' own research productivity. The issues become more complex when a nontenured faculty member has a joint appointment and must seek tenure in two departments.

Involvement in IDR provides a number of benefits, including the opportunity to participate in unique projects and to build collaborative relationships with peer faculty members in other departments.

GAINING TENURE

An interdisciplinary faculty member seeking tenure often faces two challenges beyond those faced by members working in a single discipline. Indeed, tenure and promotion criteria were listed as the top impediment to IDR by respondents to the committee survey (see Figure 4-5). First, as suggested above, IDR done by the candidate may not be valued sufficiently to compensate for a lower output of disciplinary research. Publications and other activities not recognized as being in the home department's discipline may be considered valuable but not sufficient for tenure. Similarly, reward systems at the level of dean and vice president of research do not necessarily reward IDR programs and activities.

Second, it can be difficult to find reviewers who understand the overall quality of the work, which usually lies outside the expertise of people on the tenure evaluation committee—that is, members of the department. In such

INNOVATIVE PRACTICE

BOX 4-5 Combining Interdisciplinary Research and Graduate Education[a]

In 1993, the College of Agriculture at Pennsylvania State University (PSU) benchmarked its programs with six other life-sciences departments. The goal of this exercise, which took almost 2 years, was to determine and set priorities among needed improvements at PSU. The benchmarking committee proposed to the university that a life-sciences institute be created that was truly interdisciplinary. In 1996, PSU dedicated $5 million to the effort to hire new faculty members, to create an interdisciplinary graduate program, and to build shared technical resources. How was it funded? The provost charged all departments to come up with a 10% reduction in budget—the savings were recycled to the university—and then engaged the faculty in determining new initiatives.

The resulting Huck Institutes of the Life Sciences[b] is a virtual organization comprising seven of PSU's colleges. Like the Program on the Environment and the Center for the Neural Basis of Cognition (see Box 9-5), the Huck Institutes does not have faculty lines but instead collaborates with colleges and departments to cohire new faculty members. As at the University of Illinois at Urbana-Champaign Beckman Institute for Advanced Science and Technology (Box 5-6), core facilities staffed by PhD-level directors attract faculty members to work at the Huck. In the last 7 years, the Huck helped to hire 50 new faculty members, providing 50 percent of the starting salaries and 50 percent of the startup costs. The Huck form an agreement with a department as to how faculty members will participate with the Huck. Built into the agreement is a biannual evaluation by the department chair that focuses on undergraduate education, graduate education, and research inte-

cases, it is essential to include letters from outside reviewers who can adequately explain the importance of the work. Accepting such letters may require departments to change policies that limit external letters to those written by members of equivalent departments.

Convocation Quote

For tenure, yes, it is risky. You spend a lot of time doing all this groundwork. Here I am, picking the rocks from the field for two years. I finally get the pile and I finally get to plant the seeds. You have to be at an institution where that type of effort is respected and you also have to have enough projects that you know are going to succeed, that you can afford to risk some time on those that you are not so sure about.

Victoria Interrante, professor of computer science and engineering at the University of Minnesota

gration. If at the 5-year mark a faculty member has not contributed to the Institutes, Huck will pull its funding regardless of the quality of his or her research.[c]

The Institutes encourage collaborative research alliances through a variety of mechanisms that integrate graduate training and research across disciplines. PSU provided up to $150,000 in seed money to faculty members to develop funding ideas and proposals in which faculty members from both physical and life sciences had to team up. That led to the development of nine core areas and graduate training programs in and across each.

The Huck Integrative Biosciences Graduate Degree Program offers students a venue to learn about and work in multiple disciplines. Meetings between people in different departments, in different colleges, and even on different campuses are supported by modern telecommunications facilities and equipment. Students in the program have to identify two advisers in at least two colleges or departments.[d] To promote interdisciplinarity and innovativeness in research and graduate education in the life sciences at PSU, the Huck Institutes is working with faculty members to develop interdisciplinary graduate groups; these may generate new options in existing graduate programs, new interdepartmental programs, or options in a new integrative-biosciences degree program of the Huck Institutes.

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[a]Partially derived from staff interview with institute Director C. Channa Reddy, November 11, 2003.

[b]Huck Institutes of the Life Sciences home page *http://www.lsc.psu.edu/*.

[c]For more information on Huck Institutes organization, governance, structure, and budgeting and graduate education policies, see *http://www.lsc.psu.edu/proppol.html*.

[d]Pell, E. J., Reddy, C., and McGrath, R. T. (2004) Interdisciplinary Education and Research: Penn State's Huck Institutes of the Life Sciences. Poster presented at the Convocation on Interdisciplinary Research, Washington DC, January 29, 2004.

The contribution of the interdisciplinary researcher may also be questioned by a department in which collaborative work is not the norm. For example, in mathematics, single-author papers are the norm and are an important step toward tenure, whereas in chemistry coauthorship is the norm. In other fields, papers may have many senior and junior coauthors. The difficulty in parsing contributions may be mitigated when review panels understand how to "read" the various contributions of researchers in interdisciplinary collaborations, but this is complicated by cultural differences among fields. For example, in some fields (notably mathematics and computer science), the author order in publications is explicitly alphabetical; in other fields, the author order indicates the importance of the contributions. In many fields, the best work is customarily published in journals; in other fields, such as computer science, conferences are the most prestigious publishing outlets. Those cultural differences can complicate tenure review of researchers who focus on IDR.

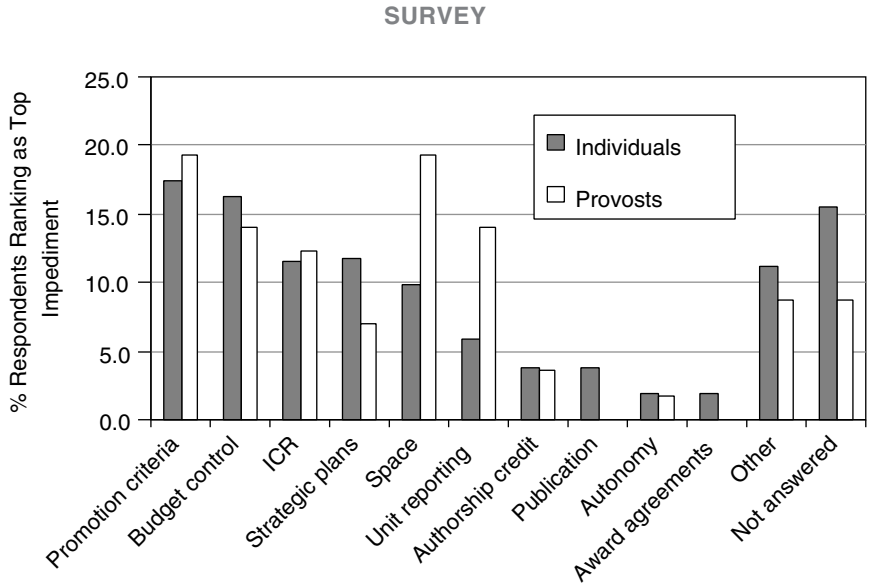

FIGURE 4-5 Top impediments to IDR.
NOTES: When asked whether there were impediments to IDR at their current institutions, 70.7 percent of the respondents answered yes, 23.2 percent answered no, and 6.2 percent did not know or did not answer. Respondents were provided a list (from Feller, 2002) and asked to rank the top five impediments to IDR at their institutions. Although the impediments cited are similar to the preconditions for IDR discussed by Klein and Porter (2002), it is interesting that "individuals" and provosts ranked impediments differently. Furthermore, impediments often mentioned in research literature–authorship credit and publication–were among the lowest ranked by both respondent groups. The impediments that were most often ranked first by "individuals" were promotion criteria, budget control, indirect cost returns (ICR), and compatibility with strategic plans. For provosts, the top impediments were promotion criteria, space allocation, budget control, and unit reporting. These differences reflect the perspectives of researchers looking for more control of their research interactions and provosts who are charged with having a global view of the university research portfolio.

Despite the apparent disadvantages, Rhoten et al. reported that interdisciplinary researchers spend about 50 percent of their total work time on extradepartmental activities related to IDR centers. About 30 percent of their sample reported that their interdisciplinary affiliations had not helped or had hindered their careers.[2]

[2]Rhoten, D. ibid. 2003.

TENURED PROFESSORS

For professors who have secured tenure and would like to pursue IDR, a critical step is to immerse themselves in the "other" field so that their work can be of the best quality and have the greatest impact. That takes substantial time–not only in learning the language of other disciplines but also in learning new value systems, aesthetics, tastes, and methods. Establishing close relationships with researchers in another discipline on the other side is critical to the productivity and quality of a researcher's work. Finding appropriate collaborators can be difficult (but see Box 4-6), especially when they work at distant institutions. Time away from regular departmental activity is helpful for immersing oneself in another field and developing the kinds of collaborations that form the foundation of much IDR.

The top recommendations for principal investigators listed by survey respondents were to increase leadership and team-forming activities (44.1 percent) and to build networks with researchers in other disciplines (20.4 percent) (see Figure 4-6).

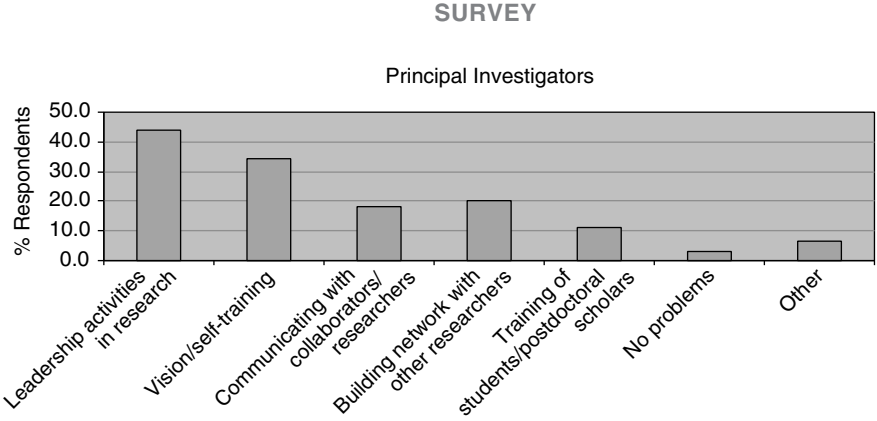

FIGURE 4-6 Recommendations for principal investigators.
NOTES: Survey Question: "If you could recommend one action that principal investigators could take that would best facilitate interdisciplinary research, what action would that be?" The top two recommendations for principal investigators given by survey respondents (n = 186) were to increase leadership and team-forming activities (44.1 percent) and to develop and clearly state their research goals and their overall vision (34.4 percent). Reports and evaluations of IDR programs have yielded similar suggestions. (See Boxes 2-4 and 8-2.) and Klein, J. T. and Porter, A. L. "Preconditions for Interdisciplinary Research." *In:* International Research Management Studies in Interdisciplinary Methods from Business, Government, and Academia, Eds. Birnbaum-More, P. H., Rossini, F. A., Baldwin, D. R. New York: Oxford University Press. 1990. pp. 11-19.

TOOLKIT

BOX 4-6 Creating and Managing Interdisciplinary Collaboration

Several institutions have decided that rather than let random molecules collide, they would help students and researchers with similar interests collaborate. The Fred Hutchinson Cancer Research Center (FHCRC) established an Interdisciplinary Research and Training Initiative in 1996,[a] which includes a Dual Mentor Program for graduate students and postdoctoral scholars, a Joint Degree Program, and a Pilot Project Fund Program (which awards about eight to 10 grants of $20,000-25,000 each year). It also funds the Interdisciplinary Club.[b] Faculty members, overseen by staff associate Karen Peterson, handle the administrative aspects of these programs.[c,d]

The Dual Mentor Program is supported by a National Institutes of Health Training Grant (T32) written by several FHCRC faculty. It has just had a successful competitive renewal. The program has funded nine graduate students, four of whom have received their PhDs, and 10 postdoctoral fellows. There are also a few privately funded fellowship slots for which international postdoctoral scholars and graduate students are encouraged to apply.

The Joint Degree Program was started in 2000. By early 2004, five graduate students had received their MS in epidemiology and were working toward their PhD in molecular and cellular biology or microbiology. Peterson was not only involved in establishing this program but also organizes an epidemiology course that every potential joint-degree student attends before applying to the program.

FHCRC scientists have the opportunity to observe daily rounds for 2-4 weeks in the Observing Stem Cell Transplant Rounds Program. This program has inspired collaborations and new career directions among faculty members and fellows, and some of the participating postdoctoral scholars decided to pursue clinical or translational research.

Continued professional advancement is also sometimes harder for those doing IDR because recognition comes from established disciplines rather than from younger or unformed fields. Thus, promotion to full professor can be more difficult for interdisciplinary researchers than for disciplinary researchers for the same reasons that the tenure process is more difficult. There are also fewer honors and awards given by professional societies for IDR than for disciplinary research (but see Boxes 7-2 and 7-3). Finally, fellowship nominations even in multidisciplinary societies, such as the American Association for the Advancement of Science, are initiated in disciplinary committees, so interdisciplinary researchers often obtain fellowship status long after disciplinary researchers of comparable quality.

Another key barrier is the attitude of other senior faculty members

Peterson also develops courses and intrainstitutional symposia on such strategic topics as proteomics, biostatistics, cell signaling, immunology, and epigenetics and cancer. The goal of these courses is to help attendees to become better collaborators by learning the main concepts, approaches, and language of a field. The courses are taught by invited faculty members and postdoctoral scholars at FHCRC and other local institutions. Attendees include graduate students, postdoctoral scholars, and faculty members.

In January 2004, Peterson began facilitating faculty team development for large IDR grants. Her role is to identify calls for proposals that may be of interest to FHCRC faculty and to alert the center and division directors. She identifies faculty members who may be interested, invites them to participate, and then "gets out of the way" to let the faculty develop the proposals. Thus far, she has worked to identify faculty members for NIH programs in integrative cancer biology and in early detection and molecular imaging.

The Student-Postdoc Advisory Committee (SPAC) provides opportunities to promote interdisciplinary programs to FHCRC's approximately 100 graduate students and 300 postdoctoral scholars. SPAC also offers travel awards that give preference to attending interdisciplinary conferences and course scholarships that many awardees use to cross-train in fields, such as computer science and statistics.

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[a]FHCRC Interdisciplinary Home Page *http://www.fhcrc.org/science/interdisciplnary/.*

[b]Paulson, T. (2003) Grassroots Interdisciplinary Training: The FHCRC Interdisciplinary Club. Science's Next Wave, Posted January 3, 2003 *http://nextwave.sciencemag.org/cgi/content/full/2002/12/30/7.*

[c]Peterson, K. (2004) The Interdisciplinary Research and Training Initiative at the Fred Hutchinson Cancer Research Center. Poster presented at the Convocation on Facilitating Interdisciplinary Research, Washington, DC. January 29, 2004.

[d]Karen Peterson, Personal Communication, April 23, 2004.

toward IDR. Some are openly scornful, claiming that it lacks the depth of discipline-centered research. This can be a serious barrier to junior and senior faculty members, as well as graduate students.

CONCLUSIONS

This chapter is meant to convey a feel for the experience of the individual researcher that is not available in quantitative form. If, as the committee believes, the cumulative effect of the specific obstacles to IDR described here is larger than any single obstacle might suggest, understanding the character and source of each obstacle becomes a high priority for institutional leaders. The next chapter will examine those obstacles from the

point of the view of the institution and suggest ways to adapt institutional structures to facilitate IDR.

FINDINGS

Successful interdisciplinary researchers have found ways to integrate and synthesize disciplinary depth with breadth of interests, visions, and skills.

Students, especially undergraduates, are strongly attracted to interdisciplinary courses, especially those of societal relevance.

RECOMMENDATIONS

Students

S-1: Undergraduate students should seek out interdisciplinary experiences, such as courses at the interfaces of traditional disciplines that address basic research problems, interdisciplinary courses that address societal problems, and research experiences that span more than one traditional discipline.

For example, students can

- Begin preparation for IDR through an IDR project or summer IDR experience.
- Approach interdisciplinarity by first gaining a solid foundation in one discipline and then adding disciplines as needed. Additional courses provide opportunities to understand the culture of other disciplines, gain new skills and techniques, and network with other researchers.

S-2: Graduate students should explore ways to broaden their experience by gaining "requisite" knowledge in one or more fields in addition to their primary field.

For example, graduate students can

- Do this through master's theses or PhD dissertations that involve multiple advisers in different disciplines.
- Share an office with students in other fields. Enhance their interdisciplinary expertise by participating in conferences outside their fields and in poster sessions that represent multiple disciplines. Those venues provide opportunities for junior researchers to present their work to colleagues outside their fields.

Postdoctoral Scholars

P-1: Postdoctoral scholars can actively exploit both formal and informal means of gaining interdisciplinary experiences during their postdoctoral appointments through such mechanisms as networking events and internships in industrial and nonacademic settings.

For example, postdoctoral scholars can

- Seek formal and informal opportunities to communicate with potential research collaborators in other disciplines and develop a network of interdisciplinary colleagues.
- Broaden their perspective through internships in industrial settings or other nonacademic settings.

P-2: Postdoctoral scholars interested in interdisciplinary work should seek to identify institutions and mentors favorable to IDR.

For example, postdoctoral scholars can seek positions at institutions that

- Have strong interdisciplinary programs or institutes.
- Have a history of encouraging mentoring relationships across departmental lines.
- Offer technologies, facilities, or instrumentation that further one's ability to do IDR.
- Have researchers and faculty members with whom the postdoctoral scholar interacts who place a high priority on shared interdisciplinary activities.

Researchers and Faculty Members

R-1: Researchers and faculty members desiring to work on interdisciplinary research, education, and training projects should immerse themselves in the languages, cultures, and knowledge of their collaborators in IDR.

For example, researchers and faculty members can

- Develop relationships with colleagues in other disciplines. Learn more about the knowledge and culture of other disciplines by participating in interdisciplinary projects.
- Actively seek opportunities to teach classes in other departments and give papers at conferences outside their own disciplines or departments. In their written and oral communications, researchers and faculty

members can facilitate IDR by using language that those in other disciplines are able to understand.

- Mentor students and postdoctoral scholars who wish to work on interdisciplinary problems.

R-2: Researchers and faculty members who hire postdoctoral scholars from other fields should assume the responsibility for educating them in the new specialties and become acquainted with the postdoctoral scholars' knowledge and techniques.

For example, researchers and faculty members can

- Familiarize themselves with the research cultures and evaluation methods of the postdoctoral scholars' fields.
- Learn about the career expectations of the postdoctoral scholars, when possible, and the demands that they will encounter in their careers.
- Guide the postdoctoral scholars toward interdisciplinary learning opportunities, including workshops, research presentations, and social gatherings.

Educators

A-1: Educators should facilitate IDR by providing educational and training opportunities for undergraduates, graduate students, and postdoctoral scholars, such as relating foundation courses, data gathering and analysis, and research activities to other fields of study and to society at large.

For example, educators can

- Provide training opportunities that involve research, data-gathering, data analysis, and interactions among students in different fields.
- Demonstrate the power of interdisciplinarity by inviting IDR speakers, providing examples of major discoveries made through IDR, and highlighting exciting current research at the interfaces of fields.
- Encourage a multifaceted, broadly analytical approach to problem-solving.
- Include as part of foundation courses (such as general chemistry) materials that show how the subjects are related to other fields of study and to society at large.
- Show through explanatory examples the relevance of IDR to complex societal problems, which often require multiple disciplines and challenge current scientific and technical methods.
- Discourage the notion that some disciplines rank higher than others.

- Create more opportunities for students to learn how research disciplines complement one another by
  - — Developing policies and practices that support team teaching of interdisciplinary courses by faculty members in diverse departments or colleges.
  - — Modifying core course requirements so that students have more opportunities to add breadth to their study programs.
  - — Provide team-building and leadership-skills development as a formal part of the educational process.