EDUCATION

Risks and Rewards of an Interdisciplinary Research Path

Diana Rhoten[1] and Andrew Parker[2]

Interdisciplinarity has become synonymous with all things progressive about research and education, not because of some simple philosophic belief in heterogeneity but because of the scientific complexity of problems currently under study (*1*). In many fields, it is argued, the easy work is finished as scholars are confronted with questions that defy easy categorization in or solution by traditional disciplinary frameworks. In response, myriad interdisciplinary programs have arisen, from federal-level initiatives such as the National Institutes of Health Roadmap and the National Science Foundation Integrated Graduate Education and Training program to campus-based endeavors like the University of Illinois Beckman Institute and the Stanford University Bio-X Program.

The rise of interdisciplinarity has also spawned a vast literature on how interdisciplinary research and training should be organized, how scientists and students will behave, and how activities of such programs could be facilitated (*2*–*6*). There have been, however, fewer studies that seek to understand empirically the links between institutional initiatives, individual attributes, and professional implications (*7*, *8*).

Between January 2002 and June 2003, we conducted surveys and interviews to analyze the interdisciplinary activities of researchers in five university-based programs funded under the NSF Environmental Research and Education portfolio (*9*). Entry into these programs was by application, invitation, and/or appointment.

We expected that because younger scientists are likely to have had more interdisciplinary exposure and less intellectual commitment to a particular field, they would be more predisposed toward these programs than their senior colleagues. At the same time, because senior faculty have accumulated greater professional freedom and more social resources, we thought that they would be more likely than their junior counterparts not only to affiliate with but also to collaborate in these programs.

Graduate students and full professors were indeed overrepresented in these programs as compared with other tenure-track researchers (see the table below) (*10*). However, apart from principal investigators who dominated large shares of interdisciplinary activity, graduate students demonstrated higher rates of interdisciplinarity than professors. Whereas 61 of 99 (62%) graduate students reported at least one interdisciplinary collaboration, only 72 of 147 professors (49%) claimed the same (*11*, *12*).

But, graduate students were also most likely to associate professional costs with interdisciplinarity. About 16% reported "negative" career effects of the program's "interdisciplinary" design (see the table). In describing real or perceived effects, graduate students indicated long-term costs. One described his position as "non-traditional, highly beneficial, but completely risky in the long run." Another explained: "For those of us who begin interdisciplinary, we get to design a [personal] renaissance to meet the needs of real-world problems. This renaissance, however, comes at a price—it may take us longer to establish ourselves in our careers." Several pointed to the greater prevalence of interdisciplinary role models among staff without tenure versus those with tenure.

When asked why they were willing to take these professional risks, graduate students frequently mentioned societal benefits. One student said "I have become very aware of the horrible inefficiency of the scientific enterprise in turning knowledge into useful products … so I came to branch out from what I was doing, to do something bigger and better, more intellectually interesting, and more practically important." Another commented: "I am sorta' on the fringe of science—but I am dealing with the core problems of society."

Our study supports the claim that "[b]right young scientists will gravitate toward the rich scientific opportunities at disciplinary boundaries" (*13*). It also suggests, however, that many still feel the tension between the scientific promise of the interdisciplinary path and the academic prospect of the tenure track.

References and Notes

1. *Bridging Disciplines in the Brain, Behavioral and Clinical* Sciences (National Academy of Sciences, Washington, DC, 2000).
2. J. T. Klein, *Crossing Boundaries: Knowledge, Disciplinarities, and Interdisciplinarities* (Univ. of Virginia Press, Charlottesville, 1996).
3. L. Salter, A. Hearn, *Outside the Lines: Issues in Interdisciplinary Research* (McGill-Queen's Univ. Press, Montreal, 1996).
4. P. Weingart, N. Stehr, Eds. *Practising Interdisciplinarity* (Univ. of Toronto Press, Toronto, 2000).
5. L. Lattuca, *Creating Interdisciplinarity: Interdisciplinary Research and Teaching among College and University Faculty* (Vanderbilt Univ. Press, Nashville, TN, 2001).
6. F. Kessel *et al.*, Eds., *Expanding the Boundaries of Health and Social Science: Case Studies in Interdisciplinary Innovation* (Social Science Research Council and Oxford Univ. Press, New York, 2003).
7. D. Stokols *et al.*, *Nicotine Tob. Res.* **5**, 21 (2003).
8. J. Cummings, S. Kiesler, *Soc. Stud. Sci.* (in press).
9. The five programs included a Human Dimensions of Global Change Center, two Integrative Graduate Education and Research Training programs, a National Synthesis Center, and a Science and Technology Center. See supplemental material for further information.
10. The affiliates across the five programs were distributed as 18% graduate students, 28% non–tenure-track faculty, 9% postdoctoral, 8% assistant professors, 9% associate professors, and 27% full professors (see the table); when the separate program percentages are averaged across the five programs, thus treating each program equally, the distributions are 32, 16, 6, 7, 9, and 28%, respectively. Both calculations point to light involvement of early career tenure-track faculty.
11. "Interdisciplinary" refers to relations that cross boundaries (e.g., engineering, physical science, life science, and social science).
12. D. Rhoten, A. Parker, unpublished data.
13. N. Sung *et al.*, *Science* **301**, 1485 (2003).

14. Supported by NSF grant BCS-0129573.

Supporting Online Material

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VIEWS ON CAREER EFFECTS OF INTERDISCIPLINARY RESEARCH

	Distribution by rank*							
	G	NTT	PD	AsP	AP	P	PIs	Total
Number surveyed	160	245	84	73	82	232	12	888
Total responses	99	155	59	47	53	147	11	571
Positive	67	104	42	34	43	109	11	413
Neutral	16	43	11	12	8	23	0	114
Negative	16	8	6	1	2	15	0	44

*G, graduate student; NTT, nontenure track; PD, postdoctoral fellow; AsP, assistant professor; AP, associate professor; P, professor; PI, principal investigator. [Source (*9*)]

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***Science* Supporting Online Material**

Risks and Rewards of an Interdisciplinary Research Path

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Sample and Methods

Study Sample

This study was conducted between January 2002 and June 2003, and the analysis of data collected from these sites remains ongoing. The five university-based interdisciplinary research programs in the study were selected by both purposive and convenience sampling methods from the population of interdisciplinary programs funded under the NSF Environmental Research and Education portfolio (Table S1).

Table S1. University-based interdisciplinary research programs: HDGC, Human Dimensions Global Change Center; IGERT, Integrative Graduate Education Research Traineeship Program; NSC, National Synthesis Center; STC, Science Technology Center. PI, Principal Investigator.

	Program 1	**Program 2**	**Program 3**	**Program 4**	**Program 5**	**Total**
Affiliates (#)	66	40	61	619	131	917
Founding date	1996	1999	1997	1995	2000	
Program type	HDGC	IGERT	IGERT	NSC	STC	
Format	Multiple institutions	Multiple institutions	Single institution	Hybrid model	Multiple institutions	
(Sub)disciplines/ specializations (#)	19	9	18	56	24	
Fields of science						
Bio- and Life	3 (5%)	18 (45%)	4 (7%)	461 (74%)	13 (10%)	499 (54%)
Computational/Mathematics	1 (2%)	0	1 (2%)	2 (2%)	2 (2%)	6 (< 1%)
Engineering	12 (18%)	3 (8%)	36 (58%)	1 (< 1%)	20 (15%)	72 (8%)
Environmental	20 (30%)	2 (5%)	0	38 (6%)	12 (9%)	72 (8%)
Geo- and Physical	5 (8%)	17 (42%)	20 (33%)	71 (11%)	75 (59%)	188 (20%)
Information	0	0	0	5 (<1%)	0	5 (< 1%)
Social and Behavioral	23 (35%)	0	0	16 (3%)	6 (4%)	45 (5%)
Arts and Humanities	1 (2%)	0	0	0	0	1 (< 1%)
Unknown	1 (2%)	0	0	25 (3%)	3 (2%)	29 (3%)
Researcher rank (*N*)						
Graduate student	14 (21%)	16 (40%)	35 (57%)	49 (8%)	46 (35%)	160 (18%)
Non–tenure track researcher	11 (17%)	2 (5%)	1 (2%)	195 (32%)	36 (27%)	245 (28%)
Postdoctoral researcher	7 (11%)	0	0	68 (11%)	9 (7%)	84 (9%)
Asst professor	7 (11%)	0	5 (8%)	53 (9%)	8 (6%)	73 (8%)
Assoc professor	4 (6%)	6 (15%)	6 (10%)	59 (10%)	7 (5%)	82 (9%)
Professor	20 (30%)	14 (35%)	12 (20%)	169 (27%)	17 (13%)	232 (26%)
PI/director (past, present)	3 (5%)	2 (5%)	2 (3%)	1 (< 1%)	4 (3%)	12 (1%)
Subtotal	66	40	61	594	127	888
Other/unknown	*0*	*0*	*0*	*25*	*4*	*29*
Total	*66*	*40*	*61*	*619*	*131*	*917*

Methods

The study was based on multiple methods from empirical social science research, combining techniques of social network analysis with those of ethnographic fieldwork. The study was divided into two "strands" of research activity. **In strand I, the social network analysis component**, survey and bibliometric methods were used to collect individual, organizational, and relational data related to the population of research affiliates in the programs of the study sample. Research "affiliation" was defined using a minimum of two of the following three criteria: "attends program-wide meetings, engages in program-related research activities, and/or receives program funding." Once these criteria were determined, "official" program affiliate lists were collected from administrators, preliminarily edited into "unofficial" but active affiliate lists (based on Web sites, reports, etc), and then confirmed as "official" and active affiliate lists by program administration.

In Part I of the survey, each researcher was asked a short series of closed-ended questions related to **individual attribute data** (e.g., professional history, disciplinary background, and interdisciplinary exposure). In Part II, each researcher was given a full roster of all researchers officially affiliated with the program. Each respondent was then asked a series of closed-ended questions designed to collect **relational data** for each and every other person on the roster: What is the nature of your interaction with this person (e.g., data sharing, paper

writing, project development, etc)?; How long have you had a relationship with this individual?; With what frequency do you interact with this individual (e.g., monthly, weekly, daily, etc)?; Via what forums do you interact with this individual? (e.g., program-wide meetings, email correspondence, formal project discussions, informal conversation, etc). In Part III of the survey, researchers were asked a series of closed-ended questions pertaining to **organizational practices and processes** of the program (e.g., collaborative projects versus independent projects, mono- versus multi- versus inter-disciplinary research strategies, reward systems and incentives, researcher time commitments, influence of program on research and career.) A copy of each researcher's curriculum vitae was also collected to (a) confirm researcher attributes related to professional background, disciplinary training, and interdisciplinary exposure; and, (b) to explore what, if any, products (e.g., publications, patents) have come from research interactions reported in and identified by the survey.

The survey was administered online in both Web-based and MS Word–based form. Survey notification, distribution, and follow-up were managed primarily via email with on-site visits. In instances where the research affiliate requested, the MS Word–based forms were mailed as hard copy through regular post. Research affiliates were asked to complete all three sections of the survey described above. In order to collect a sufficient amount of relational data required for network analysis, we offered a "short version" of the survey (which eliminated Part III of the survey) toward the end of the data collection process,

Response rates for only those affiliates who completed both of the following relational and organizational survey items discussed in the article: "strength of network relations" (relational) and "influence of program's interdisciplinary activities on career opportunities" (organizational) are shown in Table S2.

Table S2. Response to survey items on network relations and career influence. Percentage of total affiliates of that rank is shown in parentheses.

Rank of respondent	Program 1	Program 2	Program 3	Program 4	Program 5	Total
Graduate student	7 (50%)	16 (100%)	27 (77%)	24 (49%)	25 (54%)	99 (62%)
Non–tenure track researcher	7 (64%)	1 (50%)	1 (100%)	125 (64%)	21 (58%)	155 (63%)
Postdoctoral researcher	5 (71%)	0	0	49 (72%)	5 (56%)	59 (70%)
Asst professor	4 (57%)	0	2 (40%)	36 (68%)	5 (63%)	47 (64%)
Assoc professor	2 (50%)	0	3 (50%)	44 (75%)	4 (57%)	53 (64%)
Professor	11 (61%)	8 (57%)	5 (41%)	115 (68%)	8 (47%)	147 (63%)
PI/director (past, present)	3 (100%)	2 (100%)	2 (100%)	1 (100%)	3 (75%)	11 (92%)
Subtotal	39 (59%)	27 (68%)	40 (66%)	394 (664%)	71 (56%)	571 (64%)
Other/unknown	*0*	*0*	*0*	*7*	*1*	*8*
Total	*45 (59%)*	*27 (68%)*	*40 (66%)*	*401 (65%)*	*72(55%)*	*579 (63%)*

Although network analysis is an extremely useful way to understand the relationships between people in a particular group it does not necessarily uncover why certain relationships are present or absent. Thus, strand II took an ethnographic approach to understanding the context of and the dynamics between the researchers within each of the programs in the sample. Observations, interviews, and artifacts/documents were used in strand II to collect additional individual, relational, and organizational data in order to better situate the analysis of the networks above in order to gain a better understanding of the factors that shape them the networks of inter-reactions.

Results

Strength of Interdisciplinary Network Relations

Survey respondents were asked to identify other researchers with whom they had "close" relations,. "Close" was as follows: "Close refers to someone you count among your closest professional and/or intellectual collaborators … with whom you develop projects, ideas, and concepts as well as prepare papers, documents, presentations."

The number of affiliates who responded to both survey items (see Table S2) and who have at least one "close," or knowledge-producing, relation with other researchers from outside their own field of science (e.g., engineering, environmental sciences, geo- and physical sciences, bio- and life sciences, social and behavioral sciences) are presented in Table S3. The number of relations is presented by rank for each program.

Table S3. Affiliates who responded to both survey items and who have at least one "close," or knowledge-producing, relation with other researchers from outside their own field of science.

Respondent's rank	ID knowledge-producing relations					Total
	Program 1	Program 2	Program 3	Program 4	Program 5	
Graduate student						
N (with ID knowledge relations)	6	16	16	7	16	61
N (researchers)	7	16	27	24	25	99
%	85.7%	100%	59.3%	29.2%	64%	63.3%
Non–tenure track researcher						
N (with ID knowledge relations)	7	1	0	58	17	83
N (researchers)	7	1	1	125	21	155
%	100%	100%	0%	46.7%	81%	53.5%
Postdoctoral researcher						
N (with ID knowledge relations)	3	0	0	15	2	20
N (researchers)	5	0	0	49	5	59
%	60%	0%	0%	31.3%	40%	33.9%
Asst professor						
N (with ID knowledge relations)	3	0	1	19	4	27
N (researchers)	4	0	2	36	5	47
%	75%	0%	50%	52.8%	80%	57.4%
Assoc professor						
N (with ID knowledge relations)	2	0	2	15	2	21
N (researchers)	2	0	3	44	4	53
%	100%	0%	66.7%	34.9%	50%	39.6%
Professor						
N (with ID knowledge relations)	9	7	2	49	5	72
N (researchers)	11	8	5	115	8	147
%	81.8%	87.5%	40%	42.5%	62.5%	49%.
PI/Director						
N (with ID knowledge relations)	3	2	2	1	3	11
N (researchers)	3	2	2	1	3	11
%	100%	100%	100%	100%	100%	100%
Total						
N (with ID knowledge relations)	33	26	23	164	49	295
N (researchers)	39	27	40	394	71	571
%	84.6%	96.3%	57.5%	41.6%	69%	52%

Program Influence on Career Opportunities

It has been argued that interdisciplinary research presents obstacles t a tenure-track academic career. Thus, survey respondents were asked to respond to the following question by selecting "positive," "neutral," or "negative": "How much and what type of influence has the center's "interdisciplinary" or "multidisciplinary" approach had on the development of your career opportunities and professional options?" Table S4 presents the responses to this question by rank by program.

Table S4. Interdisciplinary program influence on career.

Data presentation	Program 1	Program 2	Program 3	Program 4	Program 5
N (Researchers) % (Responses by rank of those that answered this item)	**Graduate student** Pos 4 (57%) Neu 1 (14%) Neg 2 (29%) Total 7 No resp 7	**Graduate student** Pos 11 (69%) Neu 3 (19%) Neg 2 (12%) Total 16 No resp 0	**Graduate student** Pos 18 (67%) Neu 3 (11%) Neg 6 (22%) Total 27 No resp 8	**Graduate student** Pos 18 (75%) Neu 6 (25%) Neg 0 Total 24 No resp 25	**Graduate student** Pos 16 (64%) Neu 3 (12%) Neg 6 (24%) Total 25 No resp 21
	Nontenure track Pos 6 (86%) Neu 1 (14%) Neg 0 Total 7 No resp 4	**Nontenure track** Pos 0 Neu 0 Neg 1 (100%) Total 1 No resp 1	**Nontenure track** Pos 1 (100%) Neu 0 Neg 0 Total 1 No resp 0	**Nontenure track** Pos 83 (66%) Neu 36 (29%) Neg 6 (5%) Total 125 No resp 70	**Nontenure track** Pos 14 (66%) Neu 6 (29%) Neg 1 (5%) Total 21 No resp 15
	Postdoctoral res Pos 4 (80%) Neu 0 Neg 1 (20%) Total 5 No resp 2	**Postdoctoral res** Pos -- Neu -- Neg -- Total -- No resp --	**Postdoctoral res** Pos -- Neu -- Neg -- Total -- No resp --	**Postdoctoral res** Pos 35 (72%) Neu 10 (20%) Neg 4 (8%) Total 49 No resp 19	**Postdoctoral res** Pos 3 (65%) Neu 1 (20%) Neg 1 (20%) Total 5 No resp 4
	Asst professor Pos 1 (25%) Neu 2 (50%) Neg 1 (25%) Total 4 No resp 3	**Asst professor** Pos -- Neu -- Neg -- Total -- No resp --	**Asst professor** Pos 1 (50%) Neu 1 (50%) Neg 0 Total 2 No resp 1	**Asst professor** Pos 28 (78%) Neu 8 (22%) Neg 0 Total 36 No resp 17	**Asst professor** Pos 4 (80%) Neu 1 (20%) Neg 0 Total 5 No resp 3
	Assoc professor Pos 2 (100%) Neu 0 Neg 0 Total 2 No resp 2	**Assoc professor** Pos 0 Neu 0 Neg 0 Total 0 No resp 6	**Assoc professor** Pos 3 (100%) Neu 0 Neg 0 Total 3 No resp 3	**Assoc professor** Pos 35 (80%) Neu 8 (18%) Neg 1 (2%) Total 44 No resp 15	**Assoc professor** Pos 3 (75%) Neu 0 (20%) Neg 1 (25%) Total 4 No resp 3
	Professor Pos 10 (91%) Neu 0 Neg 1 (9%) Total 11 No resp 9	**Professor** Pos 7 (88%) Neu 1 (12%) Neg 0 Total 8 No resp 6	**Professor** Pos 4 (80%) Neu 1 (20%) Neg 0 Total 5 No resp 7	**Professor** Pos 83 (72%) Neu 19 (16%) Neg 13 (11%) Total 115 No resp 54	**Professor** Pos 5 (63%) Neu 2 (25%) Neg 1 (12%) Total 8 No resp 9
	PI/director Pos 3 (100%) Neu 0 Neg 0 Total 3 No resp 0	**PI/director** Pos 2 (100%) Neu 0 Neg 0 Total 2 No resp 0	**PI/director** Pos 2 (100%) Neu 0 Neg 0 Total 2 No resp 0	**PI** Pos 1 (100%) Neu 0 Neg 0 Total 1 No resp 0	**PI** Pos 3 (100%) Neu 0 Neg 0 Total 3 No resp 1

Final Notes

Although this study was systematic in its design, it was still exploratory in its effort. As such, the resulting view of interdisciplinary research practices is a detailed picture of a small number of centers in a specific arena of research at one particular time. Moreover, despite efforts to compare interdisciplinary and disciplinary actions and interactions of the subjects in our sample by looking at both interdisciplinary and disciplinary activities and networks in each program, this study lacks a proper disciplinary control group. Finally, in our efforts to complement survey data with ethnographic data so as to understand and explain the dynamics of the network structure, the interview and observation methods did capture a portion of survey nonrespondents; however, it did not capture any of the program nonparticipants. As such, the study overlooked the opinions of those not electing in or getting assigned to interdisciplinary programs, including predominantly assistant and associate professors.