Training Tomorrow's Environmental Problem Solvers: An Integrative Approach to Graduate Education

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Environmental problems are generally complex and blind to disciplinary boundaries. Efforts to devise long-term solutions require collaborative research that integrates knowledge across historically disparate fields, yet the traditional model for training new scientists emphasizes personal independence and disciplinary focus. Growing awareness of the limitations of the traditional model has spurred a reexamination of graduate training in the environmental sciences. Many institutions are implementing novel training approaches, with varying degrees of success. In this article, a group of current and former doctoral students evaluates our collective experience in one such program, the Biogeochemistry and Environmental Biocomplexity Program at Cornell University, funded by an Integrative Graduate Education and Research Traineeship grant from the National Science Foundation. We identify aspects of the program that contributed to our integrative research training experience, and discuss stumbling blocks that may arise in such programs. We conclude with recommendations for students and faculty interested in facilitating cross-disciplinary interactions at their home institutions.

Keywords: education, graduate training, Integrative Graduate Education and Research Traineeship grant, biogeochemistry, biocomplexity

Society has a growing need for scientists who have the skills and expertise to tackle the enormous complexity of contemporary environmental problems. Both the rate and spatial scale of human alteration of the global environment are unprecedented (MEA 2005), creating a demand for scientists with training that cuts across traditional disciplinary and methodological lines (Pickett et al. 1999, NAS et al. 2005, Wake 2008). The conventional emphasis on disciplinary research and intellectual independence in graduate training programs leaves many students in the environmental sciences ill prepared to secure employment and thrive in the fast-paced, solution-oriented world of environmental management (Ewel 2001). Devising solutions to complex environmental problems also requires working closely with colleagues from many disciplines, yet fostering interdisciplinary collaborations is seldom a priority at research-oriented universities. In this article, our group of current and former doctoral students summarizes the educational approach taken by the program in Biogeochemistry and Environmental Biocomplexity (BEB) at Cornell University, which was designed to enhance collaboration and integration of knowledge across traditional disciplines. We draw upon our experiences in this program to evaluate various elements of our training, with the objective of contributing to discussions about how graduate education can better prepare tomorrow's scientists to be environmental problem solvers.

The traditional model of doctoral education in the United States emphasizes research on a narrowly defined dissertation topic. Attention is focused on developing expertise in a chosen area; depth of knowledge is prioritized over breadth of knowledge across fields. While this approach has been effective in training students for academic research careers, it is often inadequate for preparing graduates to meet the expectations of nonacademic employers, certain funding sources, or the public at large (Golde and Dore 2001, Campbell et al. 2005). As of 1995, more than half of new graduates with doctoral degrees were finding employment outside of academia (COSEPUP 1995). After reviewing the current system, the National Academy of Sciences' Committee on Science, Engineering, and Public Policy (COSEPUP) recommended creating

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a broader range of funding and skill-building opportunities in academic departments, and better informing students about employment opportunities and trends (COSEPUP 1995).

Following the COSEPUP report, several investigations documented graduate student perspectives on the weaknesses of traditional graduate programs (e.g., Nerad and Cerny 1999, Nyquist and Woodford 2000, Golde and Dore 2001). These studies highlight the importance of student empowerment in defining program structure (Golde and Dore 2001). They also suggest that students desire greater opportunities to integrate interdisciplinary projects into doctoral training programs in environmental sciences (Nyquist and Woodford 2000). Remedying the shortcomings identified in the COSEPUP report and subsequent studies will benefit graduate students, faculty, nonacademic employers, and society at large as collaborative efforts become the norm in government, nongovernmental organizations, and even academia.

At Cornell University, an Integrative Graduate Education and Research Traineeship (IGERT) grant, funded by the National Science Foundation (NSF), has supported the development of a program in BEB. The BEB program focuses on physical-chemical-biological linkages within ecosystems and on the complex interactions of organisms with each other and their environment. In accordance with the objective of the IGERT program to establish a "fertile environment for collaborative research that transcends traditional disciplinary boundaries" (NSF 2009), the BEB program is structured to foster cross-disciplinary interactions between academic and nonacademic researchers with diverse expertise. It also seeks to offer graduate students a wide range of learning opportunities that integrate concepts and approaches across traditional disciplinary boundaries.

As student participants in the BEB program, we have identified specific aspects of our training that we believe have been particularly useful in preparing us to enter the collaborative world of environmental problem solving. Many of the successful aspects of the program, we think, could be implemented at other institutions without external financial support. We also draw on our collective experience to identify stumbling blocks that may arise when designing and implementing integrative research training programs. To support our conclusions, we present results from two surveys of Cornell University graduate students. The first, conducted specifically for this article, compared the training opportunities available to BEB student participants versus their peers in traditional graduate programs in the same departments. The second was initiated by the BEB program itself to assess how student participants perceive the effects of BEB involvement on their education (box 1). Finally, we offer recommendations to graduate students and faculty interested in facilitating similar cross-disciplinary interactions at their home institutions. It is our hope that this evaluation will aid in identifying broadly applicable strategies for enhancing integrative doctoral training in the environmental sciences.

Box 1. Surveys: Graduate student perceptions of opportunities and resources provided by the integrative BEB program.

An explicit objective of both the Integrative Graduate Education and Research Traineeship and the Biogeochemistry and Environmental Biocomplexity (BEB) programs is to facilitate interaction and exchange among researchers with diverse expertise. To investigate whether training opportunities and frequency of cross-disciplinary interactions differ between BEB participants and students within a traditional model of graduate education, we present data from two surveys of Cornell University graduate students. The first survey, conducted by the authors of this article, included student participants from eight departments with active members in the BEB program (biological and environmental engineering, civil and environmental engineering, crop and soil sciences, earth and atmospheric sciences, ecology and evolutionary biology, horticulture, microbiology, and natural resources). The survey was generated using SurveyMonkey software (*www.surveymonkey.com*) and disseminated by e-mail to departmental listservs. A total of 105 students completed the survey.

Students were polled about their interactions with faculty and students within and outside their home departments, and about the frequency of interactions with visitors from outside Cornell University. We focused on the types of training activities available to students and on whom they approach for advice. At the end of the survey, students were asked to indicate whether they considered themselves participants in the BEB program. Of the 105 students surveyed, 30 identified themselves as being active participants, 68 did not affiliate themselves with the BEB program, and 7 did not answer this question.

The second survey was initiated and conducted by Cornell faculty for the purpose of evaluating students' perspectives of their experiences as participants in the BEB program. The survey was disseminated to BEB students by e-mail; 46 students participated. Questions pertained to the impact of the BEB program on the educational experiences of students, and on whether students perceived their participation in the BEB program to be worthwhile.

The BEB program: Moving toward integrative graduate education

The Cornell BEB program brings together students and faculty from eight departments, as well as scientists from the Boyce Thompson Institute (Ithaca, New York) and the Cary Institute of Ecosystem Studies (Milbrook, New York). The program includes six major elements: a seminar series, workshop courses, a graduate student association (GSA), annual retreats, internal competitions for small research grants, and internship opportunities outside academia. The objective of the BEB program is not to replace the traditional departmental program, nor to stimulate the inception of a distinct degree, but to increase the educational opportunities available to graduate students within each member department (table 1).

Table 1. Community infrastructure and program elements available to graduate students in a traditional graduate program and to those in the BEB program.

BEB IGERT program	Traditional program	BEB IGERT impacts
Community		
Eight university departments, Cary Institute of Ecosystem Studies, Boyce Thompson Institute	Single university department	Increases cross-departmental interaction
Students from many departments	Students from a singe department	Facilitates frequent interaction with peers from many departments
Mentors from many departments	Mentors from single department	Expands mentorship outside of home department
Visiting scientists with expertise in diverse disciplines	Visiting scientists with expertise in discipline of home department	Facilitates interaction with scientists outside discipline
Shared resources across departments	Department resources	Expands the pool of intellectual and material resources
Program elements		
Developed by students and faculty	Developed mainly by faculty	Students have input and control over graduate training
Workshops	Structured learning experiences	Provide students with opportunities to create diverse learning experiences
Annual retreat		Forum for program development and casual social and scientific exchange
BEB seminar series	Department seminar series	Exposure to visiting scientists from diverse disciplines
BEB listserv	Department listserv	Cross-disciplinary dispersal of information and resources
Internships		Provides funding for nonacademic research experiences
BEB social events	Departmental social events	Networking opportunities with scientists of diverse expertise
BEB graduate student association	Department graduate student association	Facilitates interaction with peers across departments
Small grants for student research		Provides experience in grant writing, peer reviewing, and review panel participation
Fellowships with annual stipend		Provides funding for interdisciplinary research traineeships

BEB, Biogeochemistry and Environmental Biocomplexity; IGERT, Integrative Graduate Education and Research Traineeship.

Note: Also shown are the impacts of the BEB program on the educational experience of graduate students. While many BEB elements parallel the group activities within a department, the integrative nature of the BEB program exposes graduate students to a broader knowledge base, which facilitates holistic approaches to environmental problem solving.

The program is based on a "value-added" strategy that seeks to expand interactions across disciplines without diluting disciplinary credentials or other benefits of membership in a single department. A small proportion of BEB students have been awarded IGERT fellowships; however, a majority of students who actively participate in the program do not receive stipends, and no faculty members receive direct funding from BEB. Students indicate that involvement in the BEB program has enhanced their scientific understanding and communication skills and has been a worthwhile addition to their graduate education (table 2).

Although some elements of the BEB program parallel typical group activities within a department, such as a seminar series or graduate student association, the academic diversity of participants serves to broaden those experiences. In addition, many of the BEB program elements are unusual among programs with a more disciplinary focus. Here we briefly describe the six elements of the Cornell BEB program.

A seminar series that bridges departments. The multidisciplinary BEB seminar series exposes students to a wide array of topics and allows for direct interaction with visiting speakers representing diverse disciplines and institutions. The research interests and methodologies that visiting speakers present often lie outside the material covered in the seminar series of a student's home department, thus broadening student perspectives on scientific analysis and mitigation of environmental problems. The BEB seminar series also provides the opportunity for students to participate in one-on-one or small group discussions with experts outside their discipline. Among the discussion topics are effective communication with the public or policymakers, strategies for structuring effective graduate training programs, and comparisons of employer expectations at liberal arts colleges, nonprofit organizations, and government agencies. Students in the BEB program are directly involved in selecting and hosting speakers, thereby offering valuable professional training and increasing student investment in the program.

Workshop courses. Development of workshop courses in the BEB program is a dynamic process and provides opportunities for students and faculty to create a variety of learning experiences. Workshop topics have included learning laboratory techniques (e.g., isotopic tracers, infrared gas analysis), exploring carbon mitigation strategies, facilitating scientific collaboration, effectively communicating research topics

through the media, and forming reading groups to discuss new books (see box 2). In addition, an annual workshop is held at the Cary Institute of Ecosystem Studies to discuss topics such as ethics in science and science-policy interactions. This off-campus workshop facilitates interaction with scientists working outside academia. The interdisciplinary workshops constitute a flexible educational approach that falls outside the scope of traditional, single-discipline training, and in some cases result in publishable findings (e.g., Vadas et al. 2007a, Warren et al. 2007).

Table 2. Student evaluations of the effects of the BEB program on their graduate education.

To what extent has the BEB program caused the following changes in you?	Mean (SD)
Broadened your perspectives about science (n = 45)	3.3 (0.7)
Increased your opportunities to collaborate with colleagues in other fields (n = 46)	3.1 (0.9)
Improved your ability to explain your research (n = 44)	2.9 (0.8)
Deepened your understanding of scientific concepts (n = 44)	2.9 (0.8)
Improved your ability to collaborate with colleagues in other fields (n = 46)	2.8 (0.9)
Improved your communication skills (n = 44)	2.4 (1.0)
Increased your self-confidence (n = 45)	2.2 (1.0)

BEB, Biogeochemistry and Environmental Biocomplexity; SD, standard deviation.

Note: Students were asked to respond to the question, "To what extent would you say that the BEB program has caused the following changes in you?" with 0 = not at all, 1 = to a small extent, 2 = to a moderate extent, 3 = to a large extent, 4 = to a very large extent. All of respondents reported that their participation had been "worthwhile," and of those, 67 percent described their participation as "extremely worthwhile."

Multidepartment graduate student association. The BEB GSA is a multidepartmental and student-initiated group funded not by the IGERT but by Cornell University. It has become an influential and valued association that aids in guiding the overall direction of the BEB program. Student enthusiasm for the BEB GSA is a result of the synergies created by linking students from several departments. Weekly meetings provide opportunities for students to share their research ideas and results, provide peer review on grant proposals and manuscripts, plan activities with visiting seminar speakers, propose workshop ideas, and act as mentors to incoming students. Meetings also foster discussions among students about how the BEB program could be improved.

Annual retreat. The annual retreat is an opportunity to introduce new students to the program, refine short- and long-term program goals, and facilitate intellectual and social exchange. These retreats provide a fertile environment for large numbers of faculty and students to brainstorm, evaluate, and discuss graduate training and research. At most universities, meetings of faculty and graduate students are conducted in mutual isolation, producing a distinctly asymmetrical influence on curricula. Joint meetings of faculty and students in a casual setting encourage candid discussions of program structure and pedagogical philosophy, thereby empowering students to engage in the structuring of their education.

Small-grants competition. The BEB program funds two annual competitions for small research grants. These competitions allow participating students to seek merit-based support for their research, up to $4000 per individual. Proposals are reviewed by an NSF-style panel chaired by faculty but composed primarily of students. Service on the BEB grant panel is expected of all students who have been awarded small research grants by the program. In addition, most students participate in a presubmission peer-review feedback process conducted by the BEB GSA.

Internships. The BEB program funds internships in nonacademic institutions. The objective is to provide opportunities for students to broaden their scientific perspective and their exposure to career options. However, few students have taken advantage of this aspect of the BEB program, which requires that students seek out, arrange, and complete an internship while maintaining a reasonable timeline for graduation. Though the idea of an off-campus internship is appealing to many students, the overall time requirements away from dissertation work is more than most students are comfortable with.

Program strengths and remaining challenges

Over the six-year course of the Cornell BEB program, student participants have identified what are clear examples—from our perspective—of both the strengths of this integrative approach to graduate training and the challenges that remain to be resolved. Although this section does not cover all of these strengths and challenges, it does identify ways in which such programs can revamp graduate education, as well as suggest specific improvements. Only time will tell whether scientists graduating from integrative training programs are more successful in tackling the complexity of contemporary environmental problems, but most BEB participants feel that their broad training has indeed given them an edge as they begin their careers. For instance, current BEB students say that the program increases the opportunities and the likelihood of collaborating with scientists outside of their field (table 2).

Strengths. We describe below what we believe are BEB program strengths.

Harnessing student initiative. An emphasis of the BEB program is to create avenues for graduate students to take initiative in their own training, enabling them to include elements that are lacking in traditional graduate programs. Student-initiated activities provide leadership skills and a

Box 2. Student empowerment: An emergent property of integrative training.

One of the most beneficial aspects of our training has been student empowerment. Giving students greater control over their education cultivates a sense of ownership that enables graduate training to be greater than the sum of the programmatic parts. Program structure can encourage empowerment, but students themselves must also decide to invest the time and effort to capitalize on the opportunities provided. The Biogeochemistry and Environmental Biocomplexity (BEB) program has few top-down requirements for participation, instead relying on a student culture of engagement. In the table below we list program elements we have identified as contributing to student empowerment.

Programmatic element	Number of participants (students, faculty)	Goal	Outputs
Graduate student association	40, 0	Cross-departmental networking, presentations of research graphs, practice talks, group lunches with visiting speakers, discussion of future workshops and direction of program, peer review of manuscripts and proposals, formation of committees (e.g., to organize seminar series, retreat, and trips to BEB-affiliated institutions)	Small-grant peer-review workshop; ideas for future workshops; feedback on figures, talks, and manuscripts; contacts within and outside of home department
Annual retreat	Approximately 50, 15	Cross-departmental networking, introduce new students to program, evaluate program and discuss future direction, plan future workshops	Future workshop topics, poster session, contacts within and outside of home department
Small-grant competition and review panel	Competition: approximately 30, 0 Panel: approximately 15, 2	Gain grant writing and reviewing experience, provide funding for individual and collaborative research	Funding for research, experience serving as peer reviewer for grant competition
Seminar series coordination	7, 0	Interaction and networking with scientists outside of home institution	Exposure to new ideas and methodologies, individual and group meetings with visiting speakers
Workshops (examples below)	Variable	Enable students to develop and initiate educational opportunities	Variable; include publications, posters, data sets, training in specific research methods
Carbon dioxide mitigation	11, 1 (plus 1 technician and 2 postdocs)	Calculate a county-scale carbon budget and assess potential mitigation strategies, provide methodologies to conduct similar local-scale budgets at different localities	Vadas et al. 2007a, 2007b
Science communication	30, 3	Train scientists to communicate effectively with nonscientists, such as stakeholders, the media, and the general public	Warren et al. 2007; student final projects, including on-air radio interviews, blogs, podcasts, newspaper articles, and newspaper editorials
Isotopes as tracers	10, 1	Learn isotopic tracer methods by developing and executing a field experiment	Manuscript in preparation

sense of empowerment, and enhance cohesion within the graduate student community (box 2). The student community, in turn, provides a safe haven for students to develop and share research ideas, thereby fostering peer mentorship and collaboration. Activities such as participation on grant review panels and involvement in selecting and hosting seminar speakers further cultivate student initiative through a sense of ownership.

Transcending departmental boundaries. The structure of the BEB program facilitates interactions across departments. According to a survey we conducted of fellow graduate students at Cornell University, the BEB program has enriched the education of participants by providing access to training activities and material resources that may not be offered within their home department (figure 1). In addition, BEB participants are nearly twice as likely as non–BEB students to seek advice from faculty outside of their department, and they rely more heavily on input from peers outside of their departments (figure 2). Creating a forum for interdepartmental exchange increases the fluidity of intellectual and material resources across often-stubborn disciplinary divides. Communication skills are improved as students learn to explain their ideas and research to scientists from outside their home departments (table 2). In addition, graduate students benefit by gaining exposure to new perspectives, equipment, and methodologies (figure 1, table 2). We believe that greater interaction in turn creates fertile ground for collaborative research endeavors, which are essential to addressing complex environmental problems. These increases in cross-department interaction could be seen as distracting students from their dissertation research, but we found no differences between BEB and non–BEB PhD students in average years of study before graduating (5.7 versus 5.8 years, respectively) or average attrition rates (13.1 versus 13.8 percent per year, respectively). Thus, our experience suggests that heightened intellectual and social interaction broadens the graduate experience without detrimentally affecting student focus.

Challenges. We explore below some of the remaining challenges within the educational framework of the BEB program.

Pursuing collaborative research efforts. BEB students have conducted several large group projects (5 to 15 people) as part of workshop courses (see examples in box 2). These projects have generally been deemed successful; however, students and workshop leaders have been slow to carry them through to publication, most likely because of the higher priority given to personal research. The BEB small grants program has attempted to alleviate the financial barriers to collaborative research by specifically encouraging coauthored proposals, yet from 2002 through 2006 only 4 out of 100 funded proposals were jointly authored. Discussions among BEB students suggest that time constraints—specifically, the need to focus research efforts on personal dissertation projects and to gain disciplinary expertise—are one of the main impediments to pursuing collaborative work. The greater time demands of cross-disciplinary collaborations have been noted elsewhere (e.g., Golde and Gallagher 1999, Graybill et al. 2006, Morse et al. 2007), and are a genuine concern for students who are under pressure to impress potential employers by maximizing publications without delaying their anticipated graduation date. Collaborative work is seen to fall short of yielding the rewards necessary to justify investment at the timescale of a graduate career. Thus, a shift in institutional philosophy is required to encourage students to conduct collaborative projects during their graduate careers.

Exposure to nonacademic paths. Although the BEB program focuses on students' professional development, the emphasis is generally on the research university career track. Nonacademic careers such as employment in nongovernmental organizations and government agencies are underrepresented. As part of their participation in the BEB program, students who receive IGERT fellowships have the opportunity to pursue a funded internship during the course of their dissertation studies. However, this opportunity has been underused because of the logistical demands of arranging an internship and the time away from dissertation work required to complete the internship. Few academic advisers have encouraged students to pursue this path, and the administrative support needed for the planning and execution of internships is lacking. Hence this component of the BEB program has largely failed. According to our survey of Cornell University graduate students, relatively fewer students in the BEB program participated in internships than did their peers in traditional, single-department academic programs (7 versus 15 percent, respectively) despite the internship opportunity explicitly offered by the BEB program.

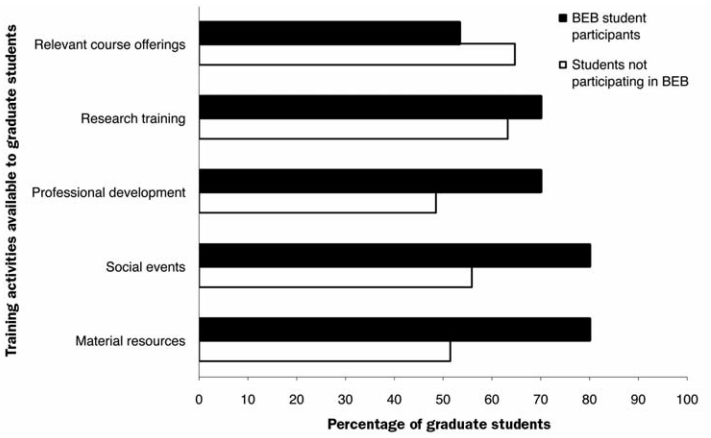

Figure 1. Educational, social, and training activities available to Cornell University graduate students who are in the Biogeochemistry and Environmental Biocomplexity (BEB) program (n = 30) or in departments with active BEB members but who do not consider themselves BEB participants (n = 68). Students responded to the following question: Which of the following opportunities are available to you? Bars represent the percentage of students who indicated that the specified training activity was available to them.

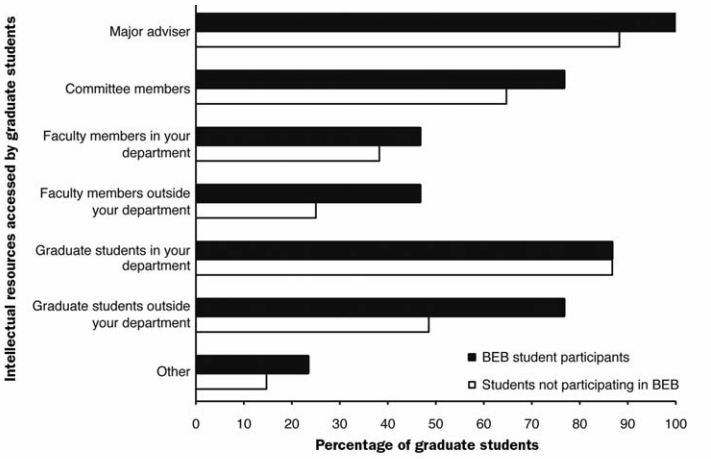

Figure 2. Intellectual resources accessed by Cornell University graduate students who are in the Biogeochemistry and Environmental Biocomplexity (BEB) program (n = 30) or in departments with active BEB members but who do not consider themselves BEB participants (n = 68). Students responded to the following question: When you encounter difficulty with your research, whom do you ask for advice? Bars represent the percentage of students who indicated that the specified intellectual resource was available to them. Resources that represent the largest differences between BEB and non–BEB students are faculty members and graduate students outside the home department (23 and 28 percent differences, respectively).

Recommendations and conclusions

We conclude that integrative training is enhanced by encouraging student initiative, transcending disciplinary boundaries, and fostering teamwork. All of these goals have diverse and lasting impacts on students, and are essential for preparing students to be effective members of the interdisciplinary teams needed to address and mitigate the global environmental

problems faced by society. We hope that sharing our perspectives on the benefits and obstacles to integrative graduate training will encourage other institutions to establish such programs with or without external funding. To this end, we offer a few final recommendations for developing integrative graduate programs, derived from our experiences as student participants in one such program.

Encourage the social side of science. Program retreats and symposia are effective ways to generate interaction within a multidisciplinary group. A social setting, in which students feel at liberty to be more informal, can help to bridge communication barriers within and across disciplines. These personal interactions also facilitate collaborations. This type of atmosphere can arise from extended periods of interaction in a new environment (e.g., off-campus retreats over a weekend), in contrast to the short exchanges and office visits that predominate in most department-based interactions.

Foster a sense of investment among graduate students. Graduate students can and should take the initiative to develop programs, workshops, retreats, and seminars. Programs developed by and for graduate students often lead to greater enthusiasm and participation. At the same time, students gain valuable professional experience by coordinating courses, seminars, and events. In particular, students often can organize workshops focused on developing professional skills or technical training with minimal financial costs.

Create a community using multidepartmental graduate student associations. We recommend forming an interdisciplinary GSA. We have found the peer mentoring and mutual encouragement within our GSA to be one of the most rewarding aspects of the BEB program. Our peers are smart, creative, and engaged. Graduate students are more willing to explore inchoate and atypical ideas with peers than with advisers, and are more comfortable making mistakes in front of peers. In weekly GSA meetings, we review each other's research proposals, give feedback on research progress and stumbling blocks, and discuss "culture of science" issues such as collaboration and job-hunting strategies. These interactions require a critical mass of graduate students, but ultimately yield a sense of unity that emboldens students to actively influence the direction of their education.

Use seminars as a frequent gathering point. Seminars bring people together and generate discussion. As graduate students, we have found that a seminar is a reliable place to find and interact with faculty, particularly when a social hour is scheduled immediately following the seminar. Our seminar series is currently supported by IGERT funds, but the seminar series predates the grant, and although funding is helpful for a seminar series, creative solutions to support a seminar series on a tighter budget may be possible (e.g., cosponsorship of interdisciplinary speakers by multiple departments). Low-cost alternatives include compiling and distributing a list of relevant departmental seminars on your campus or nearby, recruiting local or regional speakers, and inviting speakers who are visiting your area for other reasons.

Support collaborative research projects. We believe that the benefits of developing cross-discipline communication skills and the experience of tackling broad, multifaceted questions deserve consideration in the design of graduate programs. Shortages of time and funds for collaborative work outside of dissertation research could be alleviated by institutional support for coauthored dissertation chapters. This approach would facilitate completion of collaborative projects that might otherwise be perceived to have diluted value relative to dissertation research. Successful interdisciplinary doctoral education will require a paradigm shift in institutional philosophy. However, in programs that cultivate a supportive atmosphere, students can both excel in their personal research and pursue broader questions within a collaborative team.

Create opportunities for graduate students to gain nonacademic experiences. Greater awareness of nonacademic paths prepares students to make informed decisions regarding employment beyond graduate school, and enables them to proactively position themselves to be competitive in the career path of their choice. In the BEB program, graduate students have been exposed to nonacademic career paths and ideas through seminars, workshops, and personal interactions with visiting scientists. Though the internship element of the program was designed to give students experiences outside academia, few BEB students have taken advantage of this opportunity. An easily accessible network of internship contacts, as provided by many co-op programs designed for undergraduates, may increase the likelihood that graduate students will pursue internships. In addition, developing projects during internships that can be integrated into an academic dissertation may allay student concerns about delaying graduation. Regardless of the specific approach taken, encouraging students to interact with policymakers and natural resource managers is likely to enhance the real-world relevance of graduate research, diminish communication barriers, and, in the long run, produce more effective environmental problem solvers.

Our analysis of student perspectives on the BEB program at Cornell University has identified both rewards and stumbling blocks of the integrative research training approach. We argue that such programs have an important role to play by empowering students to take ownership of their education, broadening experiences in the research and social components of science, and promoting communication and collaboration among disciplines. Moreover, an integrative pedagogy need not require a longer period of graduate study or sacrifice the depth of knowledge expected of graduates. Though challenges remain, our experiences suggest that integrative training programs—by virtue of being flexible and untethered to traditional academic disciplines—cultivate intellectual and collaborative skills needed to confront the complexity of environmental problems.

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