INTRODUCTION
Growing commitment to interdisciplinary teaching and research is a national phenomenon as funding agencies such as the National Science Foundation (NSF), National Institutes of Health (NIH), universities, and research centers recognize the need for interdisciplinary collaboration in order to tackle complex social and environmental problems. The desire for interdisciplinarity stems from both the theoretical and practical priorities of academia, industry, and society. Unmet societal needs and the practical financial concerns of researchers in the face of declining governmental support for graduate education and research funding, especially for state-funded research universities, are creating conditions favorable for interdisciplinary education, training, and research. Business and public funders are particularly interested in efforts to develop practical solutions to problems that inevitably cut across disciplinary boundaries and geographic scales (Schoenberger 2001). Drawing on the diversity of perspectives and practices each discipline offers, interdisciplinary collaboration promises to provide innovative solutions to complex contemporary problems (Reich and Reich 2006).

An excellent model of interdisciplinary teaching and research training is the Integrative Graduate Education and Research Traineeship (IGERT) program initiated by NSF in 1997. Since then, more than 214 IGERT awards have been made to over 125 award sites. Substantive topics in interdisciplinary work include multifaceted globalization, climate change, human dimensions of global change, natural and human-induced hazards, sustainability, poverty alleviation, and urban growth. Because addressing such themes requires bringing together specialists in human, biophysical, nature–society, and technical realms, and attention to public policy concerns, programs such as IGERT are being established to expand opportunities for graduate students to gain experience working in interdisciplinary teams and research settings.

It is also important to recognize that interdisciplinary partnerships are not unique to the U.S. Such efforts are evident elsewhere and include opportunities for international collaboration in addressing issues of global significance. For example, geographers are exceptionally well represented in new multidisciplinary units in Australian universities (Holmes 2002), while German geographers have been very active in the German Research Foundation's (DFG) IGERT-like GRAKO (Graduiertenkolleg) interdisciplinary research program and have taken part in mutual faculty and graduate student exchanges and collaborations with the University of Washington's urban ecology IGERT program.

In this chapter we focus on emerging paradigms of interdisciplinarity and interdisciplinary praxis and offer suggestions of ways to enhance skills for research, education, communication, and management while working across disciplinary boundaries. We highlight training needs and describe experiential ways of improving them, calling attention to some of the institutional impediments to interdisciplinary work. The chapter is accompanied by a set of practical activities designed to assist faculty and graduate students who wish to be successful in meeting the challenges in interdisciplinary and transdisciplinary team efforts. Our suggestions and the activities draw heavily on our combined forty-plus years of personal experience in crossing disciplinary boundaries as students, teachers, and researchers. Attention to language, differing personal work styles, systems thinking (Senge 1990; Bellinger 1994), experiential problem-based learning (PBL) (Farley et al. 2005; White 2001); teamwork, and formal group-process training exercises (Scholtes, Joiner, and Streibel 2003) are important strategies and activities for improving the skills needed for intellectually stimulating, rewarding, and successful interdisciplinary work.

IMPORTANT DEFINITIONS
Collaborations that involve working across disciplinary boundaries are often described as multidisciplinary, interdisciplinary, or transdisciplinary. What do these terms share, how do they differ, and what research and learning strategies and approaches are most effective for such efforts to be creative and successful? All three terms refer to efforts by natural and social scientists and scholars from the humanities and professional fields to
I address a myriad of complex issues and problems in which geographers and other scholars are, or need to become, engaged in order to make useful and practical contributions to their resolution.

At the most basic level, “multidisciplinary” approaches are contexts in which two or more researchers from diverse disciplines work collaboratively toward a shared goal. In contrast, the successful applications of “interdisciplinary” approaches are those in which researchers from two or more disciplinary backgrounds come together to use innovative conceptual frameworks to understand and synthesize their respective disciplines in order to deal effectively with a research problem (Alberti et al. 2003). “Transdisciplinary” approaches involve meaning and actively engage nonacademic practitioners in collaboration with academic researchers to identify, research, and develop solutions to real-world problems (Tress, Tress, and Fry 2003). Such approaches employ a combination of appropriate theories and methodologies to solve problems with the problem being addressed determining the tools and disciplinary knowledge required to develop appropriate solutions (Graybill et al. 2006).

KEY ASPECTS OF CROSSING DISCIPLINARY BOUNDARIES

Interdisciplinary Research

Since the 1980s, and with the end of the Cold War, research institutions have been buffeted by a cacophony of political, social, and economic changes that have shifted dwindling research funds away from “basic” research to more strategic “applied” research based on societal needs (National Research Council 1994). As scholars and researchers, we are now frequently called upon and expected to contribute to ongoing and new debates on public policy. This has created an endless need for individual and disciplinary reflection and generated debate surrounding questions of advocacy versus research objectivity (e.g., see, Sonnett 2002; Campbell 2005).

 Undertaking interdisciplinary research can be a lengthy process. It takes time to learn about other disciplines and bodies of research and to come to a consensus about ways to collaborate and implement research goals. Herbert Simon considers interdisciplinary collaboration a serious business and estimates that it takes at least one year to “pick up” another person’s discipline (quoted in Lattuca 2001). It also takes time to develop a shared cognitive space or paradigm that allows participants to think about the world in similar ways (Rossini and Porter 1984). (We suggest an approach to developing such thinking through undertaking a cognitive mapping exercise; see Activity 14.3.) This process is crucial, however, as it requires shared standards and agreement on methods. For example, in the case of interdisciplinary human–environment research, the complexity of...
(1) increasing the versatility and career options of Ph.D. candidates; (2) training in teamwork and managerial skills, including those commonly required in business, industry, and private and nongovernmental sectors; (3) participating in internships; (4) providing more career assistance; and, most importantly, (5) encouraging interdisciplinary (and often international) work.

Other important recommendations include the call for increasing exposure to technology, extensive review of program requirements, program assessments, and clarification of program expectations for graduate students. Further recommendations include better mentoring for students, new reward and incentive structures for faculty engaged in interdisciplinary work, formal course work on values and ethics involved in research and teaching, and the incorporation of formal training and understanding of the global economy and environment. If these programmatic improvements were to be implemented across graduate education, the next generation of scholars would be better prepared to engage interdisciplinary projects.

Curriculum Design

In order to design effective interdisciplinary training and curricula, several procedures are necessary. The first step is to create introductory courses on both substantive and methodological topics that will make it possible for students to acquire basic skills (Goldstein et al. 2004). Second, a core set of courses that provide a broad background coupled with specialized courses drawn from different disciplines should be established (Semerjian et al. 2004). Third, suites of actively team-taught, interdisciplinary, issue or problem-based thematic courses need to be developed (discussed in more detail in the next section). The objective of such courses is to encourage students to see similarities and differences among disciplines, and begin to recognize how different disciplines approach the same problem (Manathunga, Lant, and Mellick 2006). Finally, students must have easy access to interdisciplinary curricula. This requires good advertisement and administrative support to enable students to enroll in such programs and courses (Semerjian et al. 2004).

Aside from course development, interdisciplinary exchange fellowships, which encourage graduate students to study in another discipline for a year, are useful (Manathunga, Lant, and Mellick 2006). The inclusion of guest researchers and speakers and active discussion of epistemological, vocabulary, value, scholarly ethics, and procedural differences and similarities across disciplines in and out of classrooms should also be emphasized (Shearer 2007). Implementing fieldwork, internships, and community work through service learning courses, as well as post-course work, also support the goals of interdisciplinary and multidisciplinary work (Semerjian et al. 2004).

Teaching Interdisciplinary Courses

The objectives of interdisciplinary courses are to introduce students to complex multidimensional issues, to develop a holistic understanding of problems/concepts/ideas, and to create projects that address real problems. The application of interdisciplinary work is crucial in this regard (Semerjian et al. 2004). Systems thinking and PBL are strongly encouraged as ways to approach complex, real-world problems; to motivate students to identify and research important concepts and principles; and to acquire the necessary skills, theories, and data to develop solutions (Senge 1990; Bellinger 1994; Duch, Groh, and Allen 2001). Although geography’s holistic and place-based approach is an ideal candidate for the proliferation of PBL techniques (Chappell 2006), students are rarely exposed to PBL in traditional geography courses (Pawson 2006). We therefore offer an example of PBL in Activity 14.4.

Shearer (2007) provides useful insights for developing interdisciplinary courses using the example of a cross-disciplinary, team-taught science class. The steps required in course planning include decision-making regarding content, assessment, and practical arrangements. It is important to agree on course goals, objectives, and topics and to determine who will teach each section. The planning will involve holding numerous meetings to ensure that each approach is allocated an appropriate amount of time, that topics are complementary, and that teaching does not involve unnecessary duplications. Discussion also needs to address how each participating discipline assesses knowledge and to reach consensus on assessment.

Another tool for teaching interdisciplinary courses is to conduct “interdisciplinary discussions” seminars where professors from multiple fields are continuously present and students are encouraged to discuss from each of these perspectives. Such seminars allow students to see differences and similarities between approaches (Caviglia-Harris and Hatley 2004). One particularly effective approach to interdisciplinary teaching is to use hands-on activities in which students bring systems-thinking theory and practice to bear (Senge 1990; Bellinger 1994; Goldstein et al. 2004; and see Activities 14.3 and 14.4).

Student Challenges

Students in interdisciplinary programs often struggle with their “identity” since they may not be part of a traditional departmental degree program. Furthermore, graduate students in interdisciplinary programs are often not eligible for traditional fellowship and traineeship opportunities. In some cases, graduate students teach two courses simultaneously both to satisfy the interdisciplinary program requirements and to stay funded by their home departments (Graybill et al. 2006). Such students may also have difficulties identifying and recruiting thesis committee members because, although they are intellectual collaborators, faculty members may not necessarily get credit in their home department for interdisciplinary students.
INTERDISCIPLINARY PROGRAMS

What Makes a Good Interdisciplinary Program?

Financial and institutional supports are critical for initiating and sustaining interdisciplinary teaching programs and conducting interdisciplinary research and outreach projects. Equality in participation, contributions of financial resources and their allocation, and equitable decision-making across participating institutions and programs are important (Monk, Manning, and Denman 2003). If there is administrative resistance and indiffERENCE (from presidents, deans, and department chairs) programs will have difficulties (Harris et al. 2003).

The ability to share is also an important feature of good interdisciplinary endeavors. As mentioned above, objectives, goals, knowledge, and experience must be communicated through frequent information sharing (Harris et al. 2003). Sharing "turf," building trust, and avoiding disciplinary ethnocentrism also help to prevent protectionist barriers between participants (Harris et al. 2003; Monk, Manning, and Denman 2003). Hence, the ability to communicate is a must. Again, it is important to make sure to spend time at the beginning of any collaboration developing shared understandings of concepts and ideas that promote a shared language (Bracken and Oughton 2006).

The core elements of successful interdisciplinary programs and projects are leadership, complementary missions, faculty development, and feedback (Harris et al. 2003). They require leaders who encourage participatory governance, can advocate across disciplines, share power and influence, are enthusiastic, and are able to cultivate others' enthusiasm. Effective collaborations are able to enhance the missions of other institutions, be they within the university or the community. For example, an environmental science program enabling students to participate in activities that helped improve the access and delivery of primary care in local communities not only led to greater support for the program but also resulted in positive learning experiences for the students (Semerjian et al. 2004). Efforts to reduce turf issues can also be made by fostering project teams that focus on multidisciplinary case studies and include a variety of participants such as students, field professors, and campus-based faculties. Getting feedback continually from program participants is also important in order to assess the effectiveness of programs (Harris et al. 2003; Semerjian et al. 2004).

How Are Good Interdisciplinary Degree Programs and Research Projects Developed?

Several good leads on the development of interdisciplinary programs and projects are available. For example, Monk, Manning, and Denman (2003) describe five phases in the process of developing sustained interdisciplinary research, faculty development, and outreach effort on the topic of gender and women's health along the U.S.-Mexico border. These included networking for partners, exploration to develop a common agenda and vocabulary, planning for funding and personnel resources, building for additional participation, and consolidation/transformation of the project. Graybill et al. (2006) identify three major stages—naissance ("where is my home?") , navigation ("what do I prioritize?"), and maturation ("how do I integrate and represent my scholarship?")—in an assessment of graduate student participation in the University of Washington's urban ecology IGERT program. They indicate that having a good experience in an interdisciplinary program begins by getting to know both the home department and the program through coursework, degree requirements, and interpersonal communication. In the navigation period, graduate students learn to balance and reconcile dual intellectual and institutional requirements, and to integrate the two systems. At the maturation stage, students' theoretical and practical knowledge culminate in their dissertations and in publications in suitable interdisciplinary journals. For those interested in research on the challenges of institutionalizing interdisciplinarity on university campuses and the future of interdisciplinary in general, Julie Thompson Klein's works (e.g., 1996, 1999, 2004, 2005) and the entire May 2004 issue of Futures would be useful.

Strategies for Internal and External Interdisciplinary Support

Several strategies for generating and sustaining internal and external support for interdisciplinary programs and projects have been identified:

- Institutional assessments of individual accomplishments need to recognize and reward collaborative work (Monk, Manning, and Denman 2003).
- Departments need to recognize interdisciplinary teaching contributions—often these courses are not considered "core" courses and become categorized as additional teaching service, which creates time pressures for faculty (Shearer 2007).
- Interdisciplinary cultures that support the goals and objectives of such work also need to be developed within participating units (Schoenberg 2001).
- Networking should include individuals external to the academy. By identifying program directors and personnel from community and funding organizations, collaborators are better able to generate external support for interdisciplinary programs and projects. For example, program officers from funding institutions should be invited to seminars and conferences in the exploratory and planning stages to help spark their interest in participation and support (Monk, Manning, and Denman 2003).

Institutional Challenges Faced by Interdisciplinary Programs

While interdisciplinary work does not require the existence of formal unit programs, academic and other research institutions are increasingly trying to
develop them in order to promote and facilitate new endeavors. Common challenges according to DuBrow and Harris (2006) include the following:

- **Faculty hiring, promotion, tenure, merit increase, and retention issues:**
  1. Concerns about the ability to be promoted, especially for junior faculty, make joint faculty appointments difficult. Because their home departments often do not reward such efforts, senior faculty may not be motivated to participate in interdisciplinary programs.
  2. Participation in such programs is not uniformly acknowledged across departments or rewarded when promotion and tenure decisions are made.
  3. When departments provide merit raises above the average, interdisciplinary programs rarely have the funds to match these raises.
  4. Department chairs and deans are not rewarded for encouraging participation in interdisciplinary programs by their faculty.
  5. Faculty beginning work in an interdisciplinary unit, or with a joint appointment in a disciplinary and interdisciplinary unit, often face a number of critical questions that may be controversial, ignored, or delayed, including the division of time, access to resources, how and by whom they will be evaluated, and even where they will have space.

(For discussion of related issues, see Chapter 5 “Succeeding at Tenure and Beyond” by Susan Roberts in this book.)

- **Resource allocation:**
  1. Interdisciplinary programs often do not receive the standard indirect costs from research projects that result directly from their initiatives; advance “deals” need to be made between departments and schools to share these funds.
  2. There are few ongoing sources of support for interdisciplinary programs. Even those programs that are well established often lack mechanisms to raise funds within current institutional structures. This situation inhibits the creation of “intellectual space” for faculty and students to experiment and to take risks with new academic directions.
  3. Somewhat counterintuitive is the common experience that it is almost impossible to eliminate interdisciplinary programs even if they cease to be effective and are not meeting their research and/or teaching goals.

- **Program advocacy:**
  1. Development activities such as fund-raising for interdisciplinary programs are often viewed to be in competition with departments and schools/colleges involved with the programs.
  2. There are rarely effective advocacy procedures or clear reporting lines for interdisciplinary programs within most universities’ organizational structures.

**CHOOSING TO CROSS DISCIPLINARY BOUNDARIES IN YOUR CAREER**

Making Career Choices and Assessing Career Impacts

Table 14.1 summarizes how a group of nearly 900 researchers ranging from graduate students to professors and principal investigators from five programs including a Human Dimensions of Global Change Center, two IGERT programs, a National Synthesis Center, and a Science and Technology Center viewed the career effects of interdisciplinarity. Graduate students were most likely to participate in interdisciplinary collaborations (62 percent reported participating in at least one interdisciplinary collaboration compared to 49 percent of professors). Seventy-two percent of all respondents and 67 of graduate students reported positive effects of participation in interdisciplinary projects. At the same time, 16 percent of graduate students as opposed to only 10 percent of professors who reported negative impacts (10 percent of postdoctoral fellows also reported negative impacts) of their interdisciplinary participation. Overall, graduate students considered their participation as far more intellectually rewarding and practical in providing solutions to the problems of society than professionally risky.

**TABLE 14.1 Views on career effects of interdisciplinary research.**

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

G, graduate students; NIT, nontenure track; PD, postdoctoral fellow; AsP, assistant professor; AP, associate professor; P, professor; Pis, principal investigator. Table modified to include cell percentages.


**Summary of the Benefits and Challenges of Working Across Disciplinary Boundaries**

Effective collaboration in interdisciplinary research and education prevents narrow specialization and provides contextual knowledge that better addresses complex, real-life issues (Manathunga, Lant, and Mellick 2006). Some argue that interdisciplinary learning leads to more flexible thinking, greater awareness of the strengths and weaknesses of a discipline, improved cognitive skills and higher-order thinking, greater awareness and tolerance of ambiguity, and increased sensitivity to bias, in addition to many other positive outcomes (Shearer 2007). For example, Ivanitskaya et al. (2002) provide a...
cogent overview of the processes and outcomes of interdisciplinary learning, focusing on the positive outcomes of developing more advanced epistemological beliefs, metacognition skills, and enhanced critical-thinking ability. They apply Biggs and Collis’s (1982) SOLO (structure of observed learning outcomes) Model to interdisciplinary learning outcomes to reveal a progression from declarative and procedural knowledge, to interdisciplinary concept thinking, and ultimately to a well-developed interdisciplinary knowledge structure with the ability to transfer to new interdisciplinary problems and themes.

Despite the rewards of interdisciplinary work, there are several challenges. For example, it is often difficult to integrate different disciplinary objects and methods of study, languages, and cultures (Schoenberger 2001). Disciplinary cultures are translated into epistemological commitments and self-reproducing social orders that can pose substantial barriers in interdisciplinary research and teaching. A genuine and productive interdisciplinary engagement is only possible when different disciplinary cultures are understood and worked through. Schoenberger (2001) warns against several other pitfalls common in interdisciplinary work. One is disciplinary reductionism where disciplinary knowledge is condensed into a set of facts and data that may oversimplify and stereotype a discipline. Another is disciplinary imperialism where one discipline extracts information from another discipline but does not value the discipline as a whole. Such practices prevent shared understanding and may impede collaborative efforts (Graybill et al. 2006).

Clear communication is essential in interdisciplinary contexts, although it can be difficult because of the different nuances, connotations, and denotations of terms across disciplines (Brown 1954). To avoid this problem and create shared intellectual understanding, interdisciplinary projects must allocate sufficient time at the beginning of a collaboration to develop shared vocabularies (Bracken and Oughton 2006). Not only do core concepts and terminology differ across disciplines, but in many cases so do the concepts of what constitutes valid evidence and methods. Without adequate time to communicate and share expectations, breakdown of collaboration may occur (Rhoten and Parker 2004; Graybill et al. 2006). Language may also pose a problem externally through the process of evaluation and peer review, making acceptance of interdisciplinary papers by highly rated journals difficult and affecting the career advancement of junior faculty (Marts 2003).

A FEW FINAL WORDS AS YOU PONDER YOUR EXCITING FUTURE CAREER CHOICES

For graduate students especially, we urge you most strongly to read the article “A Rough Guide to Interdisciplinarity: Graduate Student Perspective” by a cohort of urban ecology graduate students about their experience in an IGERT program (Graybill et al. 2006). The article offers a view from the graduate student perspective on the stressors and rewards of interdisciplinary training and research. We believe their report will be of value to you as you consider the numerous emerging possibilities of pursuing interdisciplinary work in your doctoral program and future academic career.

References


