A New Model for Training Graduate Students to Conduct Interdisciplinary, Interorganizational, and International Research

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Environmental challenges are often global in scope and require solutions that integrate knowledge across disciplines, cultures, and organizations. Solutions to these challenges will come from diverse teams and not from individuals or single academic disciplines; therefore, graduate students must be trained to work in these diverse teams. In this article, we review the literature on training graduate students to cross these borders. We then present a National Science Foundation Integrative Graduate Education and Research Traineeship Program at the University of Washington as a model of border-crossing graduate training focused on interdisciplinary, international, and interorganizational (I^3) collaborations on environmental challenges. Finally, we offer recommendations from this program to those considering similar I^3 training programs, including strategies for maintaining faculty buy-in, for scaffolding student training to cross borders, and for conducting focused group trips that give the students structured experience crossing all three borders simultaneously.

Keywords: interdisciplinary education, international research, interorganizational collaboration, scaffolding, problem-based training

Environmental challenges transcend disciplinary, institutional, and political borders. The complex character of these challenges stems from diverse value systems, political differences, and economic and technological disparities (MA 2005, Perz et al. 2010). Solutions must come from varied disciplines, including social and natural sciences (Borrego and Newswander 2010); solutions require the engagement and collaboration of diverse collaborators, including academia, industry, government, nongovernmental organizations (NGOs), and private citizens. Therefore, researchers working on environmental topics will need to adopt an interdisciplinary, international, and interorganizational (I^3) approach.

Environmental problems require solutions grounded in multiple disciplines (Klein 2004). However, crossing disciplinary borders is impeded by epistemological, communication, and methodological barriers that limit researchers' abilities to collaborate effectively (Manathunga et al. 2006, Cummings and Kiesler 2008, Carney and Neishi 2010). Effective collaboration may require fundamentally new ways of collective thinking and training in cross-disciplinary communication (Perz et al. 2010).

Many environmental issues are complex precisely because they transcend political and administrative borders (Perz et al. 2010), and their resolution therefore requires cross-border collaborations. For example, efforts to address climate change have involved the participation of hundreds of scientists, policymakers, and citizens from different cultural and political backgrounds (Solomon et al. 2007). Similarly, Chinese dams along the Mekong River are blamed for disrupting natural hydrologic cycles in Southeast Asian countries where people depend on the river for their livelihoods (Lu and Siew 2006) and solutions will involve collaborations between China and Southeast Asian countries.

Individual institutions are often unable to solve complex problems on their own; instead, collaboration among multiple groups or organizations is necessary. Working across organizations provides a collaborative advantage (Huxham and Macdonald 1992) whereby complementary resources, information, and ideas compensate for the limitations of the individual organizations (Perz et al. 2010). The result is a product that could not have been achieved by any one of these organizations acting alone (Huxham and Macdonald 1992). Importantly, the term *organization* can encompass both formal organizations, such as government agencies and NGOs, and local partners and stakeholders whose local knowledge can enable learning, shift management practices, and improve collaborative outcomes (Velásquez Runk 2009).

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Although working across different borders is inherently challenging, there are common, transferable skills for working across disciplines, nationalities, and organizations (Perz et al. 2010). For example, disciplinary differences are often discussed as being cultural differences (Bauer 1990), which implies that similar skills can be employed to work across disciplines and nationalities. Crossing these borders requires a broad perspective of the issue; teamwork; clear communication among the stakeholders; collaboration among people with different knowledge, values, and approaches (Dietz et al. 2004); networking; teaching and learning about complex topics; and a willingness to apply diverse methods (Muir and Schwartz 2009). These skills are not unique to crossing any one border, and once acquired, they can be applied to crossing other borders.

Given the imperative that environmental researchers work across disciplinary, national, and organizational borders, it is clear that a system is needed to train students to cross these borders. In this article, we aim to accomplish three goals toward developing such programs: First, we review and critique literature on training graduate students in I^3 border crossing. Second, we discuss a National Science Foundation (NSF) Integrative Graduate Education and Research Traineeship (IGERT) program at the University of Washington (UW), Multinational Collaborations on Challenges to the Environment (MCCE), as a model for I^3 training for graduate students. Third, we present recommendations that have resulted from our experience in the MCCE program.

Training graduate students to cross borders

Traditional doctoral programs are not designed for training students in I^3 collaborations (Borrego and Newswander 2010). Instead, most graduate programs prioritize specialization and a depth of knowledge in subfields (Nyquist 2002, Manathunga et al. 2006) and may lack training in skills that are necessary to both address environmental issues (e.g., skills to understand stakeholder perspectives; Jacobson and McDuff 1998) and prepare students for nonacademic careers (Dietz et al. 2004, Muir and Schwartz 2009). Although graduates of specialized programs are crucial to basic research on environmental questions, they may not have the diverse training necessary to participate in complex teams working to solve environmental challenges (Golde and Gallagher 1999).

Despite narrow training in graduate school, many students will pursue careers requiring broader skill sets and working across diverse borders. A significant number of doctoral students will pursue careers outside of academia (Nerad and Cerny 1999, Moslemi et al. 2009, Nerad 2010), which will require interactions across disciplines, cultures, and institutions (Nerad and Cerny 1999). Unfortunately, few programs explicitly include an interdisciplinary training, an international focus, or interorganizational experiences, which thereby disadvantages students, who will go on to work in an increasingly globalized world (Nerad 2010). Therefore, traditional graduate programs may not effectively prepare researchers to function immediately in such varied and complex settings.

In this section on graduate-school training, we first review the literature on training students to cross single borders—disciplinary, international, or organizational. In doing this, we found that the literature on interdisciplinary training is extensive and growing, whereas the literature on international and interorganizational training is less developed. Second, we discuss educational strategies applicable to I^3 training. Third, we discuss the NSF IGERT program as a formal approach to institutionalizing I^3 training in graduate education.

Training to cross one border. In this section, we review the literature on strategies used to train graduate students to cross disciplinary, national, and organizational borders.

In response to narrow training (Nyquist 2002, Manathunga et al. 2006) and the need to train students for nonacademic jobs (Nerad and Cerny 1999, Nerad 2010), there has been increased emphasis paid to interdisciplinary training for graduate students (Musante 2004). Interdisciplinary training enables students to address complex environmental problems (Ewel 2001), develops scientific researchers and educators at the leading edge of their fields (Leshner 2004), makes students more productive in scholarly publications (Tucker 2008), and improves their chances of finding jobs after graduation (Richards-Kortum et al. 2003).

Unfortunately, graduate students face barriers to interdisciplinary training, including cultural and methodological differences among disciplines (Golde and Gallagher 1999, Eigenbrode et al. 2007), competing departmental requirements, and the expectations of multiple advisers (Richards-Kortum et al. 2003). Students have trouble becoming fluent in multiple academic cultures (Boden et al. 2011), express concern that they will not become experts in a single discipline, and often see a disconnect between interdisciplinary programs and their home department (Richards-Kortum et al. 2003). In short, a central challenge in interdisciplinary training is to communicate and reconcile across disciplines while still developing skills in students' home disciplines (Golde and Gallagher 1999, Manathunga et al. 2006).

Interdisciplinary programs are designed to build community, teach interdisciplinary theory and methods (Morse et al. 2007) in a way that overlaps with the requirements in students' home departments (Newswander and Borrego 2009), and train students in multiple fields. Community building encourages the social side of science, fosters a sense of investment among students (Moslemi et al. 2009), and develops the students' sense of ownership in the process (Graybill et al. 2006). Therefore, it is important to find diverse, engaged students, create a participatory culture, and focus on interactive teaching and learning (Newswander and Borrego 2009). Tress and colleagues (2009) recommended formal introductions to other fields to help students gain a working knowledge of other disciplines. For example, Eigenbrode and colleagues (2007) presented a universally applicable "toolbox for philosophical dialogue," which can be used by students to teach other students about their disciplines, to facilitate communication, and to identify epistemological differences and similarities.

Although international training for graduate students is common in some disciplines and rare in others, little has been written on structuring and executing international programs in graduate education. However, the need for international awareness and training for graduate students is increasingly on the forefront of educators' minds. Nerad (2010) recommends both the reintroduction of foreign-language requirements in English-speaking countries and structured international collaboration. Working across disciplinary borders is often compared with working across cultural borders (Bauer 1990); we suggest, therefore, that strategies for interdisciplinary training should apply to international training. In particular, learning to anticipate uncertainties in international collaboration may be a fundamental, teachable skill (Perz et al. 2010).

Little research has been published about successful inter-organizational training for graduate students. Cummings and Kiesler (2008) found that researchers have more trouble crossing organizational borders than disciplinary borders, suggesting that training in crossing organizational borders is needed. Some programs do exist, including off-site internships (Russo et al. 2008, Moslemi et al. 2009) and international internships with host organizations (Kainer et al. 2006). Similar skills are required to cross I^3 borders (Perz et al. 2010); similar strategies can therefore be employed to train graduate students to cross all three borders.

Pedagogical strategies for I^3 graduate training. Given the need to train students to work across multiple borders to address today's complex environmental problems, we suggest three pedagogical strategies that should be emphasized to help students gain appropriate skills—teamwork, problem-based learning, and scaffolding. Programs should create opportunities for students to work in teams on I^3-style problems, starting with simple problems and building up to complicated challenges.

Complex environmental problems inevitably require large teams to address them; graduate students must therefore be trained to work on such teams. Bishop (2009) suggested that graduate students work on diverse teams through international, multidisciplinary, collaborative projects resembling workplace experiences. Training students to be good team members should include a specific focus on attending to a process (Graybill et al. 2006), carefully selecting teams, using mentors to facilitate team integration, jointly and clearly developing themes and research questions, emphasizing team problem definition and proposal writing, having a communication strategy, and enforcing the accountability of team members (Morse et al. 2007).

These teams should work on real-world problems to further prepare the students for future careers. *Problem-based learning* is student-centered learning in which the instructor facilitates the students' discovery and inquiry through solving complex problems (Dochy et al. 2003). This process helps the students gain the skills needed to apply their knowledge to situations they encounter outside the classroom (Pawson et al. 2006). Although the training in nearly all PhD programs is problem focused, the problems are often narrow and disciplinary in nature. Effective graduate training for diverse careers should include experiences based on I^3 problems.

Most important, programs training graduate students to address complex environmental issues must gradually scaffold the students' experiences rather than immediately giving them complex real-world problems to solve in teams. In scaffolded experiences, the instructor provides assistance as needed and decreases that assistance over time so that students become progressively more self-sufficient (Wood et al. 1976). Most PhD programs use the apprentice–artisan–craftsman model of scaffolding, in which student learning is supported by close association with a more-experienced practitioner; this model has also been successfully applied to a polymer IGERT program (Russo et al. 2008). Programs expecting students to start with no experience, or just traditional coursework (i.e., Bishop 2009), and to immediately tackle a large, complex, I^3 project are likely to frustrate the students. Scaffolding gives the students space to succeed and learn as complexity is added.

IGERT as a model for crossing multiple borders. Recognizing the limitations of traditional doctoral programs, the NSF developed IGERT as a formal program to train graduate students to address complex problems by working across disciplines, institutions, and organizations (NSF 2008). IGERT programs are often supplemental to regular graduate work in the student's home department (Boden et al. 2011). These programs have been broadly successful in emphasizing interdisciplinary training; helping students obtain degrees in less time; and preparing students for the science, technology, engineering, and mathematics workforce (Carney and Neishi 2010). Most IGERT programs involve coursework on interdisciplinarity and in disciplines outside of students' home departments, as well as interdisciplinary team research projects (Graybill et al. 2006, Eigenbrode et al. 2007, Morse et al. 2007, Moslemi et al. 2009).

IGERT programs must promote and integrate research across disciplines and organizations and provide students with an international perspective (NSF 2008). For example, the students in the joint program between the University of Idaho and the Tropical Agricultural Research and Higher Education Center in Costa Rica work on I^3 teams throughout graduate school (Morse et al. 2007). Other programs have opportunities for students to do internships with industry or international partners (Russo et al. 2008, Moslemi et al. 2009, Boden et al. 2011).

The MCCE program as a model for I^3 graduate training

The University of Washington's MCCE program was a systematic and rigorous I^3 training program for graduate students that included students from social work, education, engineering (civil and environmental engineering, material science and engineering, electrical engineering, chemical engineering, and computer science), biology, forest resources (natural-resource economics and ecology), geology (geomorphology), and anthropology (archaeology and environmental anthropology). Rather than working only with disciplines that address similar questions (e.g., geology and archaeology) or use similar epistemologies (e.g., electrical engineering and computer science), MCCE focused on training students to work across broad areas between fields (e.g., material science and environmental anthropology). Interdisciplinary collaborations were the foundation of our training, not the end result. MCCE trainees worked on broad environmental problems in a wide range of disciplines and countries in collaboration with people from different organizations.

MCCE required one year of coursework that included structured group trips, a pedagogical internship including an international component, and one year of support for individual international internships. Here, we describe the I^3 training program and how it provided scaffolding for us to use when we were conducting individual research overseas. Our individual international internships were the final experience of the program, and we present them as evidence of the effectiveness of our training. For brevity, we focus only on the year of coursework and the international internships in this article. The eight trainees who collaborated on this article represent all three MCCE cohorts and five disciplines (biology, ecology, natural-resource economics, geomorphology, and archaeology). We draw on our experiences, the MCCE principal investigator's final report, and informal interviews with other trainees.

Transboundary trip. Our training began with a weeklong "transboundary" trip in which we explored environmental issues common to Washington State and British Columbia (figure 1). These trips introduced trainees to the environmental challenges shared between Washington and British Columbia and helped build a sense of community among the cohort of trainees before they began the intense year of coursework. The trainees met with researchers, policymakers, government-agency staff, tribal members, industry representatives, and community members working on environmental issues on both sides of the border. This initial experience took advantage of English as a common language and built on differences in history and geography that create surprisingly disparate approaches to similar issues. Two conference presentations with MCCE students and faculty members as coauthors resulted from these experiences (see the online supplemental data for these publications and others referred to in this article, available online at *http://dx.doi.org/10.1525/bio.2012.62.3.11*).

Seminar on interdisciplinary research. The core component of MCCE was a yearlong course focused on identifying and learning to cross disciplinary, national, and organizational boundaries with their associated cultural, philosophical, linguistic, epistemological, and methodological differences. During the year, trainees presented the approach taken by their own discipline (e.g., what questions are addressed, what data are collected, and how data are analyzed) to fellow trainees and heard guest panels of interdisciplinary teams from various institutions, including academia, government, and NGOs discuss challenges and benefits of interdisciplinary and interorganizational teamwork. In the relative comfort of a team of peers, we explored theories of interdisciplinarity and strategies for working together in interdisciplinary teams. This seminar allowed the students to engage in a meaningful way with the topic of crossing disciplinary boundaries.

International group project. Also during the first year of the program, the trainees designed and executed I^3 projects. The first cohort focused on regional projects (working either with Native American tribes or on transboundary issues between British Columbia and Washington); one project resulted in a conference presentation in Vietnam with five MCCE students from four disciplines as authors. The second and third cohorts traveled with MCCE faculty members to China (2006 and 2007) and New Zealand (2007), where they collaborated with international partners from a variety of disciplines and organizations. As a result of these group projects, 100% of MCCE students worked on team projects with students from disciplines different from their own. In contrast, 66% of IGERT and 50% of non-IGERT students work on team projects while in graduate school; 64% of IGERT and 36% of non-IGERT students work on projects with students from different disciplines (Carney et al. 2006).

During the two trips to China, trainees and UW faculty members collaborated with students and faculty members from Sichuan University (SU) and staff from Jiuzhaigou National Park (JNP). During the 2007 trip, the groups followed up on several of the topics from the 2006 trip and focused on an overarching theme that examined human–landscape interactions over time (box 1). The 2006 trip resulted in one peer-reviewed paper with five authors, including two MCCE students from two disciplines and two JNP staff members from two countries. In addition, one student blogged for Grist (*www.grist.org*) while in China and wrote an article about the trip for *The Christian Science Monitor*. The 2007 trip resulted in one peer-reviewed paper with 19 authors, including seven MCCE students from four disciplines; five SU faculty members and students from two disciplines; and two park staff members, one of whom is Tibetan. The trip also resulted in four conference presentations, each including at least one author from each of the three institutions. A follow-up trip in 2008 resulted in a popular-press article with five authors, including one MCCE student and a Tibetan JNP staff member.

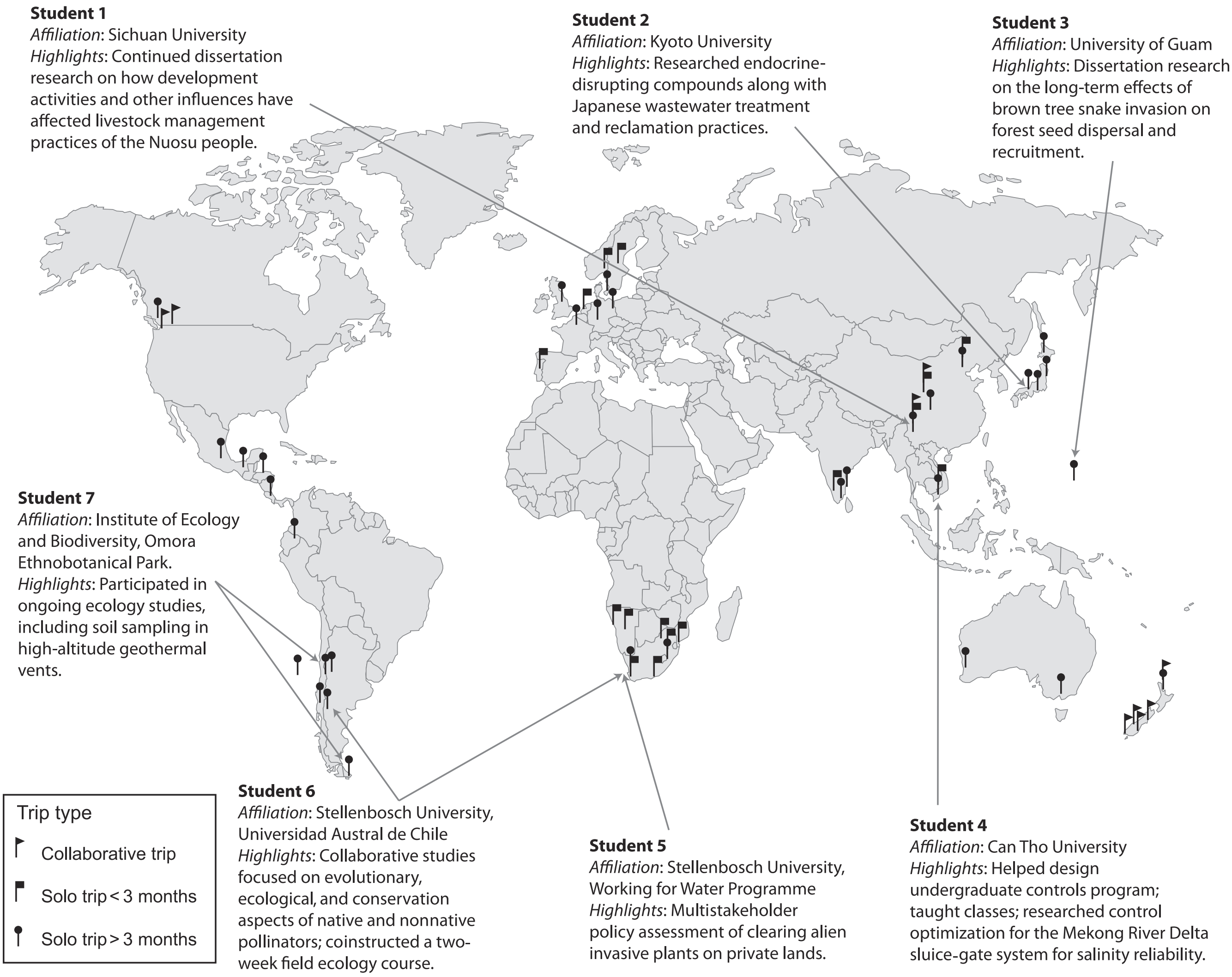

Figure 1. Diversity of locations where Multinational Collaborations on Challenges to the Environment (MCCE) students studied and traveled abroad for research and conferences. The numbers indicate the locations and brief project descriptions of selected student international internships. The sites are marked by flags to indicate long-term stays, short-term visits, and group trips. The success of the individual international internships demonstrates the overall success of the MCCE program in training graduate students to conduct interdisciplinary, international, and interorganizational (I^3) research. We provide examples of some I^3 projects and publications resulting from international internships in the supplemental material (available online at **http://dx.doi.org/10.1525/bio.2012.62.3.11***).*

Furthermore, following her PhD, one trainee received a Fulbright Fellowship to continue work in JNP that was initiated in 2007; in January 2010, she was appointed to be the first postdoctoral researcher at JNP. During follow-up work in summer 2011, she wrote for *The New York Times*' "Scientist at Work" blog.

The New Zealand trip addressed the management of an invasive diatom, *Didymosphenia geminata*. During their trip, the trainees and faculty members met with scientists, land managers, indigenous people, policymakers, and community members involved in managing *D. geminata*. The trip resulted in a conference paper presenting a new model for analyzing multistakeholder environmental issues, using the example of *D. geminata* in New Zealand as a case study; 10 of the 13 authors were MCCE students, representing seven different disciplines.

Individual international internships. The second year of funding was intended to support individual international research internships. Trainees designed their independent trips differently; some conducted dissertation research, some completed pedagogical internships (not discussed in this article), and others conducted research outside of their immediate field of expertise. Figure 1 illustrates the diverse settings in which students studied and conducted research and provides examples of how some students completed these experiences. A common theme for all of the international internships was that they applied the skills in working across borders gained

Box 1. Case study of the 2007 China trip.

Using the scaffolding provided by our first year in Multinational Collaborations on Challenges to the Environment (MCCE), we further cultivated our skills at crossing borders by participating in a group research and educational experience abroad. During this trip, we used the interdisciplinary, international, and interorganizational (I^3) approach to address the overarching theme of examining the impacts of human–landscape interactions over time.

Project participants. The I^3 team included University of Washington (UW) MCCE students and faculty members, non-MCCE UW students, Sichuan University students and faculty members, Tibetan villagers, and Jiuzhaigou National Park (JNP) science-office staff. The team members from the universities represented five disciplines: geology, ecology, cultural anthropology, archaeology, and natural-resource economics.

Project background. JNP, a United Nations Educational, Scientific and Cultural Organization World Heritage site in a Tibetan part of Sichuan Province and China's premier ecogeologic tourist attraction, receives over two million visitors annually. In addition to park visitors, there are nine indigenous villages within the park, five of which are still inhabited. The central objective for the project was to work within the I^3 framework to better understand historical and current human use of resources within JNP in order to design sustainable management policies for the future.

Working across borders in the field. Each trainee had the opportunity both to lead investigations in their area of disciplinary expertise and to participate in research teams using methods from other disciplines; all of the teams included at least one member from each of the three institutions involved in the project. For example, the ecologists developed a vegetation-monitoring protocol for a variety of habitat types in the park, and the social scientists designed a survey questionnaire to study perceptions of environmental change and traditional ecological knowledge among park residents. The ecologists participated in interview sessions with the social scientists and learned ethnographic methods that used local knowledge to help interpret landscape patterns. The social scientists in turn joined the ecology team to learn how to conduct the vegetation surveys.

Effectiveness of MCCE I^3 teamwork and benefits to JNP and trip participants.
Detailed trilingual (Tibetan–Chinese–English) interviews revealed information concerning past and present land-use that was instrumental in our ability to interpret landscape patterns in the park. Such insights would not have been possible without collaborating with the JNP cultural-resource manager, who grew up in a park village and was able to arrange interviews with local elders; nor would these insights have been possible without the Chinese language skills and ethnographic training of the social scientists, which enabled them to quickly build rapport with the local villagers and to situate their questions and findings within a local cultural context. In addition, having trainees with other backgrounds present during the interviews allowed for expansion of those interviews into areas not anticipated by the social scientists. For example, social scientists who collaborated with ecologists and geologists found that their studies provoked new questions, such as local medicinal uses of particular plant species, the use of fire to maintain agricultural fields and meadows, and terrace formation.

Similarly, it became apparent to the natural scientists that without a strong partnership with social scientists, park cultural-resource managers, and Tibetan villagers, it would have been much more difficult and time consuming to gain a complete portrait of the historical, ecological, political, and cultural processes that shaped the meadow landscapes and the history of human habitation within the park. Ethnographic interviews, in concert with ecological and geological studies, were used to corroborate, test, and contextualize each other's explanations for changes in vegetation patterns in JNP.

Our work led to a reevaluation of the landscape history in the park, a more complete understanding of the length of human habitation in the region and the role that humans play in setting modern landscape conditions, and key management recommendations to maintain meadow habitat that provides important cultural and ecological services.

during the first year of training. The breadth of topics studied in, the geographic range of, and the publications resulting from these internships demonstrate the range of interest and expertise developed through the MCCE I^3 training. Twenty-six trainees studied in 17 countries (three students only took one year of funding and did not study abroad, although one did participate in an international group trip, and another did complete short-term overseas trips individually). Japan was the most popular country (four students); three each went to Chile, China, and Canada; two went to South Africa; and one trainee traveled to each other country. Most individual internships resulted in conference presentations or peer-reviewed publications with foreign collaborators, often from other disciplines, as coauthors. At the time the MCCE program concluded in 2010, 29 MCCE students had published 32 peer-reviewed articles. (Disciplinary papers are counted only prior to graduation for students who graduated before the MCCE program ended.) Of these, four are interdisciplinary, and one includes foreign collaborators as coauthors. Of the 28 disciplinary articles, 13 are based on international work, and 8 have foreign collaborators as coauthors. In addition, the MCCE students are coauthors on 43 conference papers; of these, 14 were interdisciplinary, 7 were on international research, and 3 include international collaborators as coauthors. Of the 29 disciplinary presentations, 16 involved international research, and

8 include foreign collaborators as coauthors. As a result of both the international group trips and the individual international internships, 97% of the MCCE students worked with scientists from foreign countries in their own countries; in contrast, only 23% of other IGERT and 17% of non-IGERT students have had these collaborative experiences (Carney et al. 2006).

Time to graduation. A major concern with I^3 programs is the extended time to graduation for students, but in fact, many IGERT trainees graduate before non-IGERT students (Carney and Neishi 2010). We find that the situation for MCCE students is more complicated. MCCE did not alter requirements from our home departments and therefore required an additional time commitment, particularly during the first year of coursework. For some, this commitment was lighter than a teaching-assistant position, but for others, it was heavier than alternative funding sources. Beyond the first year, time requirements varied significantly among the trainees. For trainees who used the international internship for dissertation research, the flexibility to spend long periods of time overseas accelerated their research. Other trainees, however, used the international internship to explore new topics; although they took longer to graduate, they finished with more diverse academic training. For example, one student spent part of her international internship to work on studies outside the scope of her dissertation, but this work resulted in two peer-reviewed publications. Therefore, the students who took longer to graduate felt the additional time spent added significant value to their professional development. Because of the diverse nature of the individual internships, the trainees differed in how MCCE affected their time to graduation, but in general, the students finished slightly before or in line with departmental averages.

Recommendations for those planning I^3 programs

Here, we draw directly on our experience in the MCCE program to present the lessons that we learned. We hope the following suggestions will serve as a guide for faculty members who are considering I^3 training programs.

Secure faculty buy-in from major advisers. Choices made by graduate students are often heavily influenced by their major adviser; the students therefore need buy-in from their adviser. Few MCCE trainees were advised by faculty members who were active in MCCE, so the trainees addressed buy-in from their advisers individually. For many of the trainees, two years of stipend support and travel money helped preempt resistance from the advisers. Aside from funding, buy-in was more likely among advisers with previous or current international research experience. To secure buy-in, we recommend that students openly discuss the costs and benefits of I^3 training early in their graduate career with advisers who do not have previous I^3 experience and obtain consent from their adviser for pursuing I^3 opportunities.

Start the program with a focused group-building activity. Initiating our MCCE experience with a focused group activity was important for two reasons: (1) providing a scope to the environmental issues faced today and (2) building a team. The transboundary trips allowed us to better understand the transnational scope of environmental problems, to meet with diverse organizations working on them, and to grapple with the interdisciplinary nature of these problems. In addition, by participating in an intense and team-focused activity before starting the year of coursework, the trainees formed important bonds with their cohort. These friendships eased the upcoming difficult process of learning to communicate across disciplines. We recommend that programs training students to cross borders in research include a focused group activity at the outset of the program.

Start with crossing one of the borders before addressing the others. A focus on first crossing disciplinary borders allowed the inductees into I^3 education to form a strong scaffold base for subsequent border crossing. In this case, disciplinary borders were crossed first because we shared an academic institution (UW) and a funding agency (NSF). The practice of skills needed in interdisciplinary work (listening to others, avoiding jargon, recognizing differences in assumptions and viewpoints) prepared us to cross multiple borders simultaneously using these skills. As with other complex skills, inadequate preparation at the scaffold base will set up nearly guaranteed failure during more complex I^3 work.

Next, expand to an organized project crossing multiple borders. After learning to cross disciplinary borders, we planned and executed group research projects that deliberately crossed both national and organizational borders. Because we had already closely collaborated on crossing disciplinary borders, addressing organizational and national borders did not add significantly more training requirements. International experiences were designed so that the students had a chance to implement their new knowledge of crossing borders initially through the shared experience of the group trips. The 2007 China trip (box 1) demonstrates a successful trip in which students worked closely with students from other disciplines and universities, as well as park staff and indigenous people.

The students should develop the research question and plan for the trip. The collaborative team projects were more successful when the students defined the project of interest, communicated with international collaborators, and planned research as a team. During the 2006 China trip, the students designed discipline-focused research projects but not an overarching research theme for the trip. The 2007 trip was more successful because of the cohesive nature of the proposal. The students participating in the project developed potential research themes involving their diverse disciplines, contacted international partners about their goals, designed an overarching research question, and outlined disciplinary subquestions. This cohesiveness and student independence enabled student ownership of the project.

Group trips should engage previously established partners. During both China trips, MCCE teams collaborated with SU and JNP, both of which were already partners with UW. UW's history of working with both organizations in a variety of disciplines helped smooth the collaboration. In contrast, the New Zealand trip relied on preexisting connections in only one faculty member's discipline, which was shared by none of the trainees on the trip. In order to encompass every participant's interests, the group chose to focus on a very broad topic (learning about New Zealand stakeholder concerns, which were synthesized and used to illustrate a model of environmental decisionmaking), rather than collaborating with existing international contacts to create practical new solutions to existing problems. We recommend that trips of this type build on preexisting relationships in a variety of disciplines to engage the students as they learn to cross borders in a productive environment. If this is not possible, we recommend that groups build in additional time to facilitate relationship building prior to project design.

Regular communication within the group and switching subgroups helps to facilitate learning on the group trips. Regular communication while conducting the international group trips was essential to our keeping focused on the overarching research question and to not becoming consumed by individual disciplinary projects. On all three international group trips, daily debriefing meetings were held to facilitate progress reports, to discuss problems that we had encountered, and to plan for the following day. In China in 2007, we added a team-swapping element. Thus, ecologists worked in the field with the geology team and vice versa, social scientists joined geology and ecology teams, and natural scientists participated in social-science team research. The New Zealand members worked as a single team throughout the trip and took leadership roles relevant to their disciplinary expertise. This experience of working directly with students from other disciplines solidified the benefits of crossing borders in research for the trainees.

Students should be given autonomy but held accountable. The MCCE trainees were given complete flexibility in where to conduct their individual international internships. This gave the trainees ownership over the experience and allowed them to complete projects contributing to dissertation research, thus maintaining buy-in from their advisers. The diverse locations made it more difficult for the MCCE faculty members to supervise and advise the students, but earlier scaffolding enabled the students to excel with individual research. The trainees were held accountable to the MCCE faculty and wrote proposals for their internships, as well as progress and final reports on their time overseas. The MCCE staff and faculty members were extremely supportive and responsive to us, both while we were planning to go overseas and during our internships. As a consequence, these experiences were productive for career building, measured by joint publications and continued collaborations.

Conclusions

In this article, we present MCCE as a model of border-crossing training for graduate students in which problem-based learning and teamwork are scaffolded to help students first learn to cross a single disciplinary border and then to cross multiple borders, thus better training them for diverse future careers. The recommendations outlined above can be adapted for program leaders seeking to design a program to facilitate similar I^3 training. The core elements of these recommendations can be summarized as follows: First, encourage students and work with other faculty members to secure buy-in from major advisers. Second, plan a group-building activity to introduce the program participants to each other and their varied backgrounds. Third, provide adequate opportunity to the students to work across disciplinary borders before working across international and interorganizational borders. Fourth, allow ample time for the students to define and plan their project of interest for an international research trip. Fifth, build on existing relationships with international contacts and foreign institutions. Sixth, engage in frequent, even daily, within-group communications. Finally, allow the trainees flexibility in choosing where they work individually.

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