FORUM

Training a New Scientist to Meet the Challenges of a Changing Environment

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The transboundary nature of global environmental change demands collaborative, multiscale, interdisciplinary research [*U.S. National Academy of Sciences,* 2005]. This requires "a new kind of scientist" [*Schmidt and Moyer*, 2008]; collaborators must develop both sufficient understanding of one another's work and the skills to integrate data sets and expertise. Although numerous interdisciplinary academic programs have emerged to address this demand, success varies widely. While many address cultural and financial impediments to interdisciplinary research [*Weingart,* 2000; *Rhoten*, 2004], there is little discussion of the skills that facilitate interdisciplinary scholarship and how to obtain them.

As early-career researchers in global environmental change, we broached this topic with our peers: alumni of the Dissertations Initiative for the Advancement of Climate Change Research (DISCCRS) and New Generation of Polar Researchers (NGPR) programs, which aim to foster interdisciplinary collaborations among recent Ph.D.s in social, natural, and physical sciences. In June 2010 we sent an e-mail inviting DISCCRS and NGPR alumni to participate in an online survey. With three open-ended and 14 constrained-choice questions, the survey could be completed within 15 minutes. To develop a portrait of interdisciplinary training of climate researchers, we focused on (1) the role of interdisciplinarity in graduate training and (2) the skills and techniques used on a regular basis and how they were acquired.

Survey results indicate that successful interdisciplinary work requires training beyond the typical university curriculum as well as a large network of mentors to serve as teachers and collaborators.

Survey Findings

Of the 197 alumni of DISSCRS and NGPR, 62 individuals completed the survey, for a response rate of 31%, consistent with Web-based surveys [*Cook et al.,* 2000]. More than 75% of survey respondents earned Ph.D.s in the past 5 years (n = 57, the number of respondents to the question) and reported a primary dissertation concentration in the life (38%), physical (33%), or social sciences (23%); nearly half (49%) reported a secondary concentration, and 11% reported a tertiary concentration (n = 61). During their graduate training, the majority of respondents (87%) completed credit hours in a field of study other than their primary concentration (n = 61). The current work of survey respondents mirrors the primary concentration of their dissertation research, but more respondents reported integrating secondary (64%) and tertiary (32%) concentrations (n = 56); three quarters reported engaging in interdisciplinary research (n = 62).

In a nonexclusive question on the role of professional experiences in their training, respondents identified (5, extremely helpful; 1, nominally helpful) fellowship programs (average rating = 4.1), informal mentors (4.0), fieldwork (4.0), graduate advisors (3.9), graduate committees (3.9), earned degrees (e.g., M.S. and J.D.) (3.8), and peer interaction/support groups (3.8) as helpful to framing and conducting their interdisciplinary research (n = 37). Most respondents (n = 37) identified the following professional relationships as "extremely helpful" (i.e., 5) to conducting interdisciplinary research: advisor (51%), informal mentor (46%), graduate committee (44%). Reflecting the challenges of the new scientist, 70% of respondents (n = 47) reported the following "inhibitions" in their pursuit of interdisciplinary experiences: did not know about opportunities (28%), difficulty identifying collaborators (17%), funding (17%), graduate advisor (15%), administration (13%), graduate committee (6%).

Early-career global change researchers reported gaining multiple technical skills (e.g., statistical analysis and computer programming) during graduate school (n = 60). More than half of those skills were acquired via informal means, with nearly a quarter of skills self-taught; however, coursework and advisors also were important sources of training (Figure 1a). Modes of learning varied. For example, while statistical analysis was learned primarily via coursework (47%), computer programing was often self-taught (63%), and data collection skills (50%) and field techniques/instrumentation skills (68%) were acquired from field experience and graduate advisors. Although most (59–60) respondents reported three or more skills obtained in graduate school, 85% found the need to expand their skill set to enhance their current research. In an open-ended question, 45 respondents identified those additional skills to be primarily in the realms of data analysis and communication (Figure 1b).

Improving Interdisciplinary Training

Interdisciplinary programs provide coursework in a variety of disciplines; however, many of the analytical and communications skills required for tackling complex problems are not part of the curriculum. The study identified communication, data collection/analysis, and computer programming/modeling skills as key to interdisciplinary research, yet they are primarily self-taught or learned from informal mentors. Furthermore, our findings highlight the importance of professional relationships in training new scientists. Cross-disciplinary graduate committees and informal mentors can provide technical and emotional support in an academic environment unreceptive to interdisciplinary work. These student-mentor relationships can build and sustain interdisciplinary research.

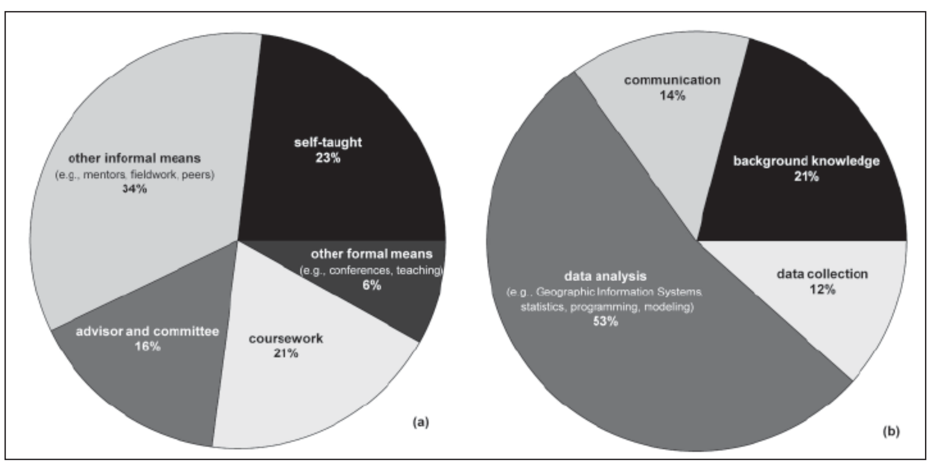

Fig. 1. (a) Means of acquiring skills during graduate school to conduct interdisciplinary research. "Formal" refers to organized modes of learning, while "informal" refers to avenues sought out and created by the student. (b) Types of skills acquired since completion of a Ph.D. to enhance global change research. See text for descriptions of categories.

As advisors, students, and mentors, we all have a responsibility to cultivate professional relationships and define adequate training. Advisors should recognize and accept personal and programmatic limitations and facilitate additional training for the interdisciplinarily inclined student. Students should seek help early in project development, identifying mentors, and training opportunities. Established scholars should respond to contact from a student across campus—its importance to that student may be immeasurable. The first task of an interdisciplinary training team is to identify opportunities for students to obtain pertinent skills. While self-instruction enhances creativity and independence, it can also be time-consuming and ineffective compared with group or professional instruction; thus both modes are necessary.

Although there remain many challenges to interdisciplinary work (e.g., disciplinary "languages"), we can do more to support students as they confront these challenges. A broader task is to structure or restructure interdisciplinary graduate programs to provide mentors upon matriculation and support formal training in the skills and techniques that are fundamental to new scientists. In turn, students can act, with skills and confidence, to disentangle the growing complexity of global environmental change.

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MEETINGS

Applying Geodesy to Hydrologic Cycle Monitoring

IGCP 565 Workshop 3: Separating Hydrological and Tectonic Signals in Geodetic Observations; Reno, Nevada, 11–13 October 2010

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The third International Geoscience Programme (IGCP) 565 workshop took place in Nevada. There were 57 participants from 11 countries representing universities, national laboratories, and government agencies. A series of plenary presentations was followed by breakout sessions addressing topics that included the advances needed to improve modeling algorithms for applications of geodesy to hydrology, working with the Group on Earth Observations (GEO) Water Cycle Community of Practice, and developing a hydrogeodetic data portal.

The presentations and discussions underlined the added value in applying geodesy to support hydrologic cycle monitoring and modeling, especially terrestrial water storage. However, before the full benefits of the emerging field of hydrogeodesy become exploitable, there is a need to reduce model uncertainty through validation with point to basin observations; to increase consistency in processing and modeling displacement, gravity variations, and hydrologic processes; and to develop new technologies that merge scale mismatches. Improving accuracy and stability of the geodetic reference frames will extend the applicability of geodesy to hydrologic problems. In tectonically active areas, joint interpretation of tectonic and hydrologic signals is required. Ground truth networks are needed at a higher density and with quality control protocols that ensure accuracy.

A limitation for the hydrologic application of satellite gravity measurements, such as the Gravity Recovery and Climate Experiment (GRACE), is the low spatial resolution. GRACE can indirectly yield terrestrial water storage change at submonthly time scales and at 100,000-square-kilometer space scales. In many geographical areas, Global Navigation Satellite System (GNSS) observations of surface displacements have a much higher spatial resolution. Combined assimilation of GRACE with Global Positioning System (GPS) and in situ gravity observations in hydrological models has been proposed as a way to overcome this limitation, but land water storage changes derived from GRACE and GPS agree well only in limited areas. Reasons for the disagreement identified at the workshop include inconsistencies in data processing and spatial filtering and, most important, biases of the land water storage through tectonic and other processes not accounted for. Therefore, the development of a modeling framework for the joint estimation of tectonic and hydrologic signals was recommended.

A primary recommendation of the workshop is a pilot project in California that would demonstrate the utility of hydrogeodesy by merging geodetic information with hydrologic modeling via assimilation, leading to technology transfer to African nations through a similar project in the Nile Basin. The California Central Valley, where more than half of U.S. fruits and vegetables are grown, is a region rich in groundwater and surface water observations. A dense GPS network provides high-resolution information on surface displacements, which can be combined with GRACE to derive land water storage variations with high spatial resolution. A key question is whether the same approach will also apply in regions of Africa.