Trends in Interdisciplinary and Integrative Graduate Training: An NSF IGERT Example

Philip E. Martin and Brian R. Umberger

In a report entitled *Reshaping the Graduate Education of Scientists and Engineers* (National Academy of Sciences, 1995), the Committee on Science, Engineering, and Public Policy proposed a modified PhD training model that retains an emphasis on intensive research experiences, while incorporating additional experiences to prepare graduates for an increasingly diverse job market. The National Science Foundation (NSF) subsequently instituted the Integrative Graduate Education and Research Traineeship (IGERT) program to foster interdisciplinary training of doctoral students. Faculty in kinesiology graduate programs are often well positioned to contribute to such interdisciplinary training programs. We highlight an example of such a program, specifically the NSF IGERT program on Musculoskeletal and Neural Adaptations in Form and Function at Arizona State University. Both benefits and challenges of IGERT participation are considered.

The benefits of interdisciplinary or integrative training in academic disciplines of all types have been discussed and touted for many years (e.g., Allen, Bentley, Donovan, Ney, & Stover, 2002; Crane et al., 1998; Greaves & Hill, 1997; Hagoel & Kalekin-Fishman, 2002; Wickware, 2000). Further, some would argue that many interesting discoveries are made at boundaries or areas of overlap where two or more disciplines meet (e.g., Dogan & Pahre, 1990). Disciplinary and professional activities linked to biological and biomedical sciences, which arguably includes many kinesiology programs, offer many excellent examples of interdisciplinarity and the benefits of interdisciplinary training. Departments of Kinesiology, with links to a diverse set of parent disciplines from the life, physical, and social sciences and the humanities, are well positioned to take advantage of interdisciplinary exchange in undergraduate and graduate education.

Philip E. Martin is with the Department of Kinesiology at Penn State University, University Park, PA 16801. Email: pem11@psu.edu. Brian R. Umberger is with the Department of Kinesiology at Arizona State University Tempe, AZ 85287.
In 1995, the National Academy of Sciences, in collaboration with the National Academy of Engineering and the Institute of Medicine, published a report entitled *Reshaping the Graduate Education of Scientists and Engineers*. Prepared by the Committee on Science, Engineering, and Public Policy (COSEPUP), the report recommends the development of a modified model for PhD training, one that retains the strengths of the existing system, most notably the emphasis on intensive research experiences, while also providing additional experiences that enhance versatility and expand career options for scientists and engineers. COSEPUP argues that the demand for scientists and engineers remains strong but suggests there are indications of a slowdown in the growth of university positions, a reduction in the demand for individuals who are traditional, basic scientists, and an increase in nonresearch and applied research and development opportunities. Further, COSEPUP suggests graduate education of scientists and engineers should prepare students for an increasingly interdisciplinary, collaborative, and global job market.

In presenting recommendations for reshaping graduate education, COSEPUP considered several strategies for achieving the desired goal of developing scientists who are more adaptable and versatile and display a broader set of skills. Developing degree programs that offer an alternative to highly focused and narrow research training by incorporating less intense research experiences and greater emphasis on applied problems and nonresearch applications was one strategy considered but ultimately rejected by COSEPUP. This is akin to discussions within kinesiology about the most appropriate balance between breadth and depth of graduate training within and across subdisciplinary areas of our field. Should we be training generalists, highly focused research scholars, or some form of hybrid that reflects depth of training in a particular subdiscipline complimented by breadth of knowledge in one or more related areas? None of these three alternatives would completely fulfill COSEPUP recommendations, although a hybrid model would more closely match the recommendations. Rather, COSEPUP suggests doctoral training must be expanded so as to provide both a highly focused research experience and additional experiences that broaden an individual’s skill set. In kinesiology, this may take the form of increased exposure to other subdisciplinary areas as well as exposure to a broader set of nonacademic opportunities and experiences.

**The NSF IGERT Initiative**

In response to the call to reshape graduate education, the National Science Foundation (NSF) is presently experimenting with an alternative approach in graduate education that capitalizes on and encourages interdisciplinary training. The NSF Integrative Graduate Education and Research Traineeship (IGERT) program was initiated in 1997 and “is intended to catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative new models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries” (http://www.nsf.gov/home/crssprgm/igert/intro.htm).

The NSF makes approximately 20 awards per year. Total funding can reach as high as $2.95 million over five years. Annual support can not exceed $550,000,
the majority of which must be dedicated to doctoral student stipends and related educational and training expenses. An additional $200,000 is available in the first year of program support to enhance the research environment through the purchase of shared research equipment and other unique research materials. Up to $100,000 in additional funding each year may be requested to stimulate international activities, e.g., short term trainee experiences in foreign institutions and reciprocal visits by foreign scholars and students to participating U.S. institutions.

IGERT programs must include a variety of features that serve to stimulate interdisciplinary exchange among a diverse group of faculty and students. Programs must integrate interdisciplinary research activity with innovative graduate curricula and training methods. Trainees must be exposed to state-of-the-art research methods and equipment, experimental techniques and paradigms, and educational methods that draw from multiple disciplines. Opportunities for professional and personal skill development (e.g., communication, teaching, and mentoring skills) and career development (e.g., internship, special laboratory, or academic experiences outside the university) must be provided. Instruction in ethics and the responsible conduct of research must also be reflected in programmatic offerings. Successful programs are those in which the importance and coherence of the interdisciplinary theme are effectively articulated and the research and educational activities are well integrated.

An NSF IGERT Example: Musculoskeletal and Neural Adaptations in Form and Function, Arizona State University

Because of existing collaborative relationships with colleagues in other disciplines, faculty in graduate programs in kinesiology are often well positioned to contribute to unique interdisciplinary training programs. An example is the NSF IGERT program on Musculoskeletal and Neural Adaptations in Form and Function at Arizona State University (ASU). Initiated in Fall 2000, the program originally brought together 20 faculty representing nine academic departments and research centers at ASU and four Phoenix area clinical science facilities (Figure 1). The program draws upon disciplinary knowledge from comparative morphology, neurophysiology, biomechanics, motor control, mathematics, and computer science for the purpose of studying interactions between biological structure and function of the musculoskeletal and neural systems involved in locomotion and upper extremity manipulative behaviors (e.g., reaching and grasping, tool or utensil use). The interplay between structure and function is considered from broad evolutionary and development perspectives, including consideration of degenerative processes associated with various neural and musculoskeletal diseases and injury, recovery through rehabilitation, and aging. The goal of the training program is to prepare research and teaching scholars with a substantially broader set of skills and experiences than would normally be offered through training in a more traditional PhD program in a single discipline.

Two factors contributed substantially to the development of the diverse and extensive faculty collective and the research and training emphasis reflected in the IGERT proposal to the NSF. The first was the existence of numerous research and graduate training collaborations. For example, four faculty from the Department
of Kinesiology, all of whom were original members of the IGERT faculty, had well established interactions with selected faculty in the Departments of Bioengineering and Anthropology at ASU and the Neurobiology Program at the Barrow Neurological Institute in Phoenix. These interactions were reflected in joint research projects, training programs, and graduate student mentoring in biomechanics and motor control. The second factor that contributed to the development of the IGERT program was a unique collaborative, cross-college undergraduate teaching effort. Four faculty representing the Departments of Anthropology, Bioengineering, and Kinesiology developed a multidisciplinary upper division undergraduate elective course addressing the relationships between fundamental structure and movement function. This effort underscored the value of preparing students who could assess fundamental human movement phenomenon from multidisciplinary perspectives and the feasibility of an interdisciplinary instructional approach. This experience contributed directly to the development of the research and training focus and the core curriculum for the new IGERT program.
Core Curriculum and Student Mentoring

In order to become a trainee in the IGERT program, a student must be admitted into one of the four core PhD programs (anthropology, bioengineering, biology, exercise science) that serve as the foundation for the IGERT program. This ensures that trainees collectively reflect diverse biological and engineering backgrounds. The IGERT program capitalizes on the existing strengths and program requirements of each student’s “home” academic program (Figure 2). The IGERT core curriculum, which reflects a minimum of 15 semester credits, is devised to supplement the program requirements of the individual PhD programs and to ensure trainees are exposed to a broader set of research skills. Three newly developed laboratory-based courses serve as the foundation for the IGERT core: anatomy and biomechanics, neurophysiology and neurobioengineering, and computation and visualization. These courses provide experience with human cadaver dissection; experimental research techniques in biomechanics, muscle physiology and mechanics, neurophysiology, and motor control; and three-dimensional computer simulation and visualization of the musculoskeletal system and movement. A biweekly research seminar is one of the most important elements of the IGERT program for several reasons. First, it provides the forum for discussions of research ethics and scientific conduct, a required element of all NSF IGERT programs. Second, it reflects the most successful mechanism of bringing together many of the participating faculty and trainees on a regular basis. Third, the seminar is used not only for sharing information about ongoing research activities of program faculty and trainees, but also for bringing leading research scholars to campus. Visits by these scholars are normally scheduled over a two-day period. In addition to presenting a formal research seminar, the invited guests are engaged in more informal discussions with IGERT trainees and program faculty. Discussions between invited guests and trainees are often structured around several recent publications of the guest, which trainees review and discuss internally in the week prior to the guest’s visit. The final element of the IGERT program requirements is an internship experience, which is designed to further enhance the practical experiences of the trainees. These capitalize on existing relationships between program faculty and professionals in various laboratory, clinical, and industrial settings.

A dual mentoring structure provides an additional mechanism for enhancing the interdisciplinary training of students. In addition to a primary mentor from the student’s home academic program, each trainee must also identify a secondary mentor from one of the other academic programs. The secondary mentor assists in shaping the trainee’s program of study and research plan and provides opportunity for additional research and laboratory experiences outside the facilities of the student’s home academic program.

Program Research and Training Facilities

The IGERT program capitalizes on an extensive and diverse array of research laboratories, facilities, and equipment that support the scholarly activities of program faculty. These include motor control and biomechanics labs in the Department of Kinesiology, neuromechanical control and motor control and rehabilitation labs in the Department of Bioengineering, neurobiology lab in the Department of Biology, and comparative morphology lab in the Department of
Anthropology. Two additional supporting facilities on the ASU campus include the PRISM (Partnership for Research in Stereo Modeling) Laboratory and the Institute of Human Origins (IHO). PRISM, which supports technology for recording, manipulating, and creating three-dimensional digital and physical models of a wide variety of structures, assists in generating muscle and bone geometry for complex musculoskeletal models. It also serves as a primary laboratory facility for the IGERT core course on Computation and Visualization. IHO contains a large and unique collection of early human and primate fossil casts and supports the evolutionary element of the training program. A new laboratory for anatomy and biomechanics, dedicated to the IGERT program, was developed for the study of musculoskeletal functional morphology and mechanics. Facilities for cadaver dissection, measurement of cadaver joint motion and tendon excursion, and
measurement of muscle fiber and sarcomere lengths were incorporated into the new lab.

Program Strengths and Challenges

The ASU IGERT Program on Musculoskeletal and Neural Adaptations in Form and Functional is now in its third year of operation. Thus, the impact of the training program on the careers of program trainees cannot yet be assessed effectively. It is possible, however, to comment on several program strengths as they relate to fundamental concerns expressed by COSEPUP in Reshaping the Graduate Education of Scientists and Engineers (National Academy of Sciences, 1995) and goals of the NSF IGERT initiative (National Science Foundation). First, the ASU IGERT program retains an important characteristic of traditional disciplinary graduate training by providing focused and intensive research experiences for trainees. The foundation for these experiences is set by the structure and requirements of participating doctoral programs and complimented by additional experiences incorporated into the IGERT program. Second, the program has a clearly articulated and comprehensive interdisciplinary theme centered on interactions between biological structure and function of the musculoskeletal and neural systems involved in locomotion and upper extremity manipulative behaviors. The program brings together faculty and trainees who reflect diverse backgrounds and experiences for considering structure/function interactions. Third, the program transcends traditional disciplinary boundaries and facilitates exchange between faculty and trainees who probably would not have interacted in the absence of the program. This is not to suggest that interdisciplinary collaborative efforts in research and graduate training were not occurring prior to the initiation of the program. As previously noted, ongoing interdisciplinary activity was one of the critical factors that led to the successful IGERT proposal. Rather, the IGERT program seems to have expanded the boundaries for interdisciplinary exchange. This has been especially true at the trainee level, where an ever growing group of students, representing four different doctoral programs, interact closely and regularly over a several year period, not just within a single course as might happen under normal circumstances. Fourth, the program exposes students to a broad base of state-of-the-art research and educational tools and technologies. This is accomplished through formal training in IGERT core courses, exposure to a more diverse set of research scholars via the IGERT seminar, and research experiences in multiple laboratory settings. Finally, IGERT funding provides a mechanism for offering highly competitive stipends and additional support for trainees in the form of funding for travel to professional meetings and for small needs for research equipment and supplies. This provides a significant recruiting tool for IGERT faculty.

The ASU IGERT program also faces some substantive challenges. COSEPUP recommended modification of doctoral training programs such that they retain an emphasis on intensive research experiences, while providing additional experiences that enhance versatility and expand career options for trainees (National Academy of Sciences, 1995). This effectively increases the demands placed on doctoral trainees. The ASU IGERT program design reflects a similar phenomenon. Trainees must fulfill the program requirements of their home academic units while also fulfilling the additional requirements of the IGERT program (a minimum
of 15 semester credits of course, seminar, and internship activity). Although many of the IGERT experiences can also fulfill requirements of the individual academic programs, trainees periodically face conflicts between academic program and IGERT demands. Such conflicts surface most frequently in the form of a trainee needing to be in two places at once. For example, IGERT core courses are time consuming and intensive laboratory courses that occasionally overlap with other courses and program activities within the home academic units. IGERT program faculty periodically confront similar time conflicts. Faculty members also face the challenge of structuring workload assignments so that the instructional needs within their academic unit and the IGERT program are fulfilled and an overload in instructional commitments is avoided. These issues of time conflicts, course scheduling issues, and workload assignments are part of the broader challenge of coordinating schedules and activities of approximately 20 program faculty and 10-15 trainees representing 13 academic programs, departments, research, and clinical facilities (Figure 1). From an instructional perspective, one of the greater challenges for faculty relates to adapting the level of instruction for the diverse technical and quantitative backgrounds of IGERT trainees. For example, biomechanical and computer simulation emphases draw heavily from program content in engineering sciences. Establishing an appropriate level of quantitative content so that all program participants are exposed to a quality and challenging experience is difficult to achieve. Finally, comentoring of trainees by faculty in different academic programs can be challenged by differing graduate program cultures. In addition, the practice of having students spend significant time outside of their home laboratory and in another faculty member’s laboratory can be disruptive to the ongoing research activities in both labs.

Closing Comments

A fundamental goal of the NSF IGERT initiative is to catalyze a cultural change in graduate education through the development of training programs that integrate knowledge and practices of multiple disciplines. Unfortunately, it won’t be possible to determine if this goal has been fulfilled for many years. Stated somewhat differently, it is unclear whether the IGERT initiative, in the form of an interdisciplinary program like that at ASU, will stimulate sufficient interdisciplinary and collaborative relationships among faculty so that teaching and research efforts reflected within the program will be sustained when NSF funding ends. Nevertheless, it is our impression that the benefits of participation in the ASU IGERT program outweigh the challenges. The program provides considerable opportunity for trainees to gain a broader set of research skills that should make them more versatile in their future professional activities.

References


