

Chapter 1: IGERT and the Landscape of Interdisciplinary Science and Graduate Education

Since the 1980s, institutions that conduct research in concert with graduate education have been buffeted by political, social, and economic changes. The end of the Cold War led to major cuts in defense spending, and resulted in research funding that grew less rapidly than inflation for the first time since the end of World War II. Changes were forced not only by fiscal constraints, but also by a shift of emphasis from a more open-ended support of “basic” research to the support of “strategic” research oriented toward specific national economic, educational, environmental, and other societal needs. Legislators and society at large began to expect scientists and engineers to contribute to new debates on public policy, help improve our competitive position in global markets, create high-value jobs, and improve the education of citizens at many levels.¹

Such changes in funding and perspective were accompanied by a more insistent concern and immediate stress on the system—namely, the failure of a substantial proportion of Ph.D. graduates in many fields to find employment in the basic research positions for which they had been trained. While the demand by non-traditional employers grew fast enough to absorb most graduates, many employers noted that Ph.D. graduates’ training was so specialized that they were neither suitably prepared for entry-level jobs nor able to readily adapt to non-academic settings.

The cumulative effect of labor market shifts and the concomitant ascendancy of applied research highlighted the graduate education system’s inattention to meeting the full range of societal needs for advanced talent in science and engineering. While the U.S. has no federal human resources policy for advanced scientists and engineers, it has become increasingly important to recognize the potential contribution of graduate education to a wide array of national needs through career preparation for professional service, applied research and development, and consulting. In order to address this national problem, the National Academy of Sciences Committee on Science, Engineering, and Public Policy (COSEPUP) Report of 1995 recommended that graduate education:

- shift graduate student support to education/training grants to bring about institutional change;
- make science and engineering programs more flexible and provide more options for students, so they acquire a broader skill range, and become more versatile;
- control time to degree;
- provide better and more timely career information and guidance while maintaining diversity and excellence in research;
- attract more women and minorities; and
- bring major participants together to discuss these issues.²

¹ National Research Council, *Federal Support of Basic Research in Institutions of Higher Learning*, Washington, DC, National Academy of Sciences, 1994.

² Committee on Science, Engineering and Public Policy (COSEPUP), *Reshaping the Graduate Education of Scientists and Engineers*, Washington, DC, National Academy Press, 1995.

The COSEPUP authors believed that these changes could be made without disrupting the traditional commitment to basic research, and turned to universities (with the assistance of national and state governments, industry, business, and others) to reshape graduate education to address current national needs and realities.

The national discussion about doctoral education has been framed by subsequent research on graduate education, including four studies in particular: Maresi Nerad and Joseph Cerny's *PhDs: 10 Years Later Study* (1999)³, Jody Nyquist's *Re-Envisioning the Ph.D. to Meet the Needs of the 21st Century* (2000),⁴ Chris Golde and Timothy Dore's *At Cross Purposes* (2001),⁵ and the Woodrow Wilson National Fellowship Foundation-supported *Responsive Ph.D.* program.⁶ Each examined graduate education from a different perspective: Nerad from that of Ph.D. recipients ten years after graduation, Nyquist from that of nine different stakeholder groups,⁷ and Golde and Dore from that of students in their third year of graduate study. The fourth endeavor, the Woodrow Wilson National Fellowship Foundation-supported *Responsive Ph.D.* program, had the goal of "sharpen[ing] into major recommendations for change the findings of several recent studies and projects on doctoral education." They focused on what they call the three "P's": paradigms, practices, and people.

Despite their diverse perspectives, findings and recommendations across these studies were remarkably similar to each other, and to those of the COSEPUP report. All of these authors emphasize the importance of:

- **Increasing the versatility, and therefore the career options, of Ph.D. candidates** (1) through training in skills commonly required in business, industry, and the private sector, including teamwork and managerial skills, (2) through participation in internships, and (3) through the provision of more career assistance and job placement; and
- **Encouraging interdisciplinary work**, not solely in support of wider career options but also, as noted in the *Responsive Ph.D.*, for the encouragement of "adventuresome research."

³ Nerad and Cerny's study surveyed nearly 6,000 PhDs who completed their graduate education in six disciplines between 1983 and 1985 (www.educ.washington.edu/COEWebSite/Cirge/HTML/research_projects.html).

⁴ Nyquist's study also includes a compendium of more than 300 "best practices" at participating institutions; this highlights the movement toward innovative strategies and actions for change within the academy (<http://www.grad.washington.edu/envision/practices/index.html>).

⁵ Golde, C.M. & Dore, T.M. *At Cross Purposes: What the experiences of doctoral students reveal about doctoral education* (www.phd-survey.org), Philadelphia, PA: A report prepared for The Pew Charitable Trusts, 2001.

⁶ According to their website (www.woodrow.org/responsivephd), the Woodrow Wilson National Fellowship Foundation received a beginning grant from The Pew Charitable Trusts. They are working with 14 Ph.D.-grant universities to test and develop a model for innovation and change.

⁷ Nyquist's stakeholder groups are research universities, teaching universities, K-12 education, government funding and hiring agencies, business and industry, foundations, professional societies, educational organizations, and graduate students.

These two thrusts are instrumental to the notion put forth both by Nyquist and the *Responsive Ph.D.* of **doctoral graduates as citizen scholars** who use their scholarship and creativity to address the needs of society.

Other suggested **programmatically improvements** included:

- inculcating values and ethics,
- increasing exposure to technology, and
- incorporating understanding of the global economy and environment.

Better preparation for a variety of professorial roles was addressed through recommendations to involve students in departmental and university governance and to provide broad pedagogical training.

Some authors also addressed the **structure of doctoral programs**, suggesting that programs:

- review Ph.D. program requirements and courses to ensure that they contribute to the programs' educational goals and to ensure the shortest possible time to degree;
- clarify the doctoral programs' expectations for graduate students;
- provide (adequate/good/multiple) mentoring for students, reward faculty for such mentoring, and conduct annual reviews of student progress; and
- improve program assessment by students and communicate with students about their experiences.

Some of the reports also emphasized the need for more racial/ethnic diversity among Ph.D. recipients. The *Responsive Ph.D.* pointed out that, while retention earlier in the educational pipeline is a crucial part of the solution to this problem, doctoral programs must do their part in improving recruitment and retention strategies. Finally, several reports stressed the importance of creating partnerships with all groups involved in graduate education, either as producers or utilizers, to bring about the changes recommended.

The IGERT Program

As of 2001, then, notions of needed graduate education reform were very much in discussion, and there was some consensus in the literature as to the direction of the needed reform. This consensus may well have reflected the pressures on graduate education – from those who hire Ph.D. recipients, from the increasingly interdisciplinary direction of research itself, from graduate students as the consumers of graduate education, and from the needs and demands of the larger society. However, regardless of scholars' consensus on next steps, most doctoral programs remained within the traditional paradigm: students worked within a single department, apprenticed to a single professor, and engaged in narrowly focused coursework and research. Their expected career goal was to remain in the academy as professors. Breaking this mold would conceivably require will, time, effort, and resources.

NSF has played a significant role in stimulating and supporting changes of the sort recommended in the reports cited above through its use of graduate traineeship awards. NSF introduced the Graduate Research Traineeship (GRT) program in 1992, followed by the Integrative Graduate Education and Research Traineeship (IGERT) program in 1997. Because these student support grants are given to institutions rather than to individual students, faculty awardees in the institutions have the opportunity to create new paradigms for graduate education.

NSF's GRT program funded 157 projects from 1992 through 1995. The program sought to stimulate the development of graduate training environments that promote and sustain broader participation in areas of national science and technology priority. GRT projects extended the traditional concept of graduate science, technology, engineering, and mathematics (STEM) education to include educational interactions, mentoring, and professional development opportunities above and beyond focused research with one major professor.

IGERT incorporates many successful components of GRT and in addition focuses specifically on supporting interdisciplinary graduate training. As of Spring 2005, there were 125 IGERT grant awards nationwide, which had supported over 2900 students.⁸ Institutions awarded an IGERT grant currently receive approximately \$3 million over five years, the bulk of which is distributed as traineeships to doctoral students who take part in a new interdisciplinary or multidisciplinary STEM graduate education program. With over \$300 million⁹ in committed funds since the program's inception, the IGERT program represents a substantial investment in graduate education on the part of the NSF.

The IGERT program is intended to encourage science and engineering Ph.D. programs to provide their students with the technical, professional, and personal skills needed for the changing career options of the 21st century, and has the following stated purposes:¹⁰

- Educating U.S. Ph.D. scientists and engineers who will pursue careers in research and education, with the interdisciplinary backgrounds, deep knowledge in chosen disciplines, and technical, professional, and personal skills to become, in their own careers, leaders and creative agents for change.
- Catalyzing a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries.
- Facilitating diversity in student participation and preparation, and contributing to the development of a diverse, globally-engaged, science and engineering workforce.

⁸ IGERT Distance Monitoring Web System, 2005.

⁹ Information presented by NSF staff at the 2005 Meeting of IGERT Participants held May 19 and 20, 2005 in Washington D.C.

¹⁰ Integrative Graduate Education and Research Traineeship (IGERT) Program, Program Solicitation, NSF 05-517.

The IGERT Program Solicitation lists the features NSF expects funded projects to incorporate. The expected features parallel very closely those put forward in the current reform literature discussed above. Grouped under the major points cited earlier, IGERT's programmatic expectations include:

Increasing the versatility, and therefore the career options, of Ph.D. candidates:

- Provisions for the development of personal and professional skills (e.g., communication, teamwork, teaching, mentoring, leadership);
- Opportunities for career development, such as internships and mentoring in various settings (e.g., industry, national labs, academic institutions, non-U.S. institutions);

Encouraging interdisciplinary work:

- A comprehensive interdisciplinary theme that serves as a foundation for traineeship activities;
- Integration of interdisciplinary research with innovative graduate education and training mechanisms, and other educational features that foster strong interactions among participating students and faculty within and across disciplines;

Programmatic improvements:

- Exposure to a broad base of state-of-the-art research and educational tools and methodologies;
- Instruction in ethics and responsible conduct of research;
- Fostering of an international perspective;

Structure of doctoral programs:

- A strategy for recruiting, mentoring, and retaining U.S. graduate students, including members of groups underrepresented in STEM fields;
- A strategy for formative and summative assessments of project performance;
- An effective administrative and organization management plan; and
- Institutional commitment to a supportive environment for integrative research and education.

Thus, the IGERT program is located within the main thrust of current graduate education reform. By supporting interdisciplinary graduate education projects, NSF is seeking to stimulate and support innovative change in graduate STEM education. Because the overall IGERT program is flexible, allowing each individual grantee considerable latitude to operationalize its own IGERT project, NSF is encouraging the development of new ideas that allow for accommodation to specific institutional contexts. There is much to be learned from this series of experiments in innovative graduate education.

Recent Changes in the Literature of Reform

Have the reforms discussed above had a noticeable effect? It appears that they have, at least within some graduate schools. In 2004, Catherine Stimpson, Dean of the Graduate School of Arts and Sciences at New York University, wrote a review for the *Chronicle of Higher Education*¹¹ stating that today's graduate students are more likely to “find diversity among the people in your seminars, to be taught how to teach, to learn how to enter ‘the profession’ and also how to use a degree outside the academy, to hear your graduate school worry how long it will take you to get your degree, and to enter programs that weave disciplines together.” All of these are goals that the reforms discussed above sought, and would applaud.

Even as these reforms within graduate education have been accepted generally and at least partially implemented, however, other concerns have surfaced. In the same review, Dr. Stimpson expressed “deep anxieties” about graduate education and the American research university in 2004. Her major concerns were three-fold:

- American graduate education is dependent on international students (83 percent of humanities doctorates are awarded to U.S. citizens, but just 60 percent of science and 43 percent of engineering doctorates). She cautions that this influx of international students is not reliable, both because of the growing competition from graduate education in the students' homelands or from Canadian, European, and Australian universities, and because post 9/11/01 American visa policies are deterring foreign students from seeking to enter the United States.
- American students will not be available to fill this potential void, because of American attitudes towards science education and science. Pathways to the sciences, beginning in middle school, are inadequate for leading American boys and girls of all races and ethnicities into science as a profession. As Stimpson writes, “we have opted for importing human capital instead of richly blending local and international intelligences.”
- All universities, except the very richest, are being ground down by financial difficulties – governments are asking more of public institutions and giving them less with which to do it. Public funds cover a smaller proportion of public university's costs, despite overwhelming evidence that research and education are fundamental to the growth and well-being of modern society.

These concerns were foreshadowed by, among others, the National Science Board in their *Companion to Science and Engineering Indicators 2004, An Emerging and Critical Problem of the Science and Engineering Labor Force*.¹² They highlight the lack of growth in the number of U.S. citizens who are training to become scientists and engineers and the decline in availability of people from other countries, while the number of jobs requiring scientific training continues to grow. They also point to the need for a sustained, long-term commitment to address this problem, given the length of the educational pipeline to the workforce. Their recommendations emphasize education: “The Federal

¹¹ “Reclaiming the Mission of Graduate Education.” (<http://chronicle.com/weekly/v50/i41/41b00601.htm>), June 18, 2004.

¹² National Science Board, *Companion to Science and Engineering Indicators 2004, An Emerging and Critical problem of the Science and Engineering Labor Force*, Arlington, VA: National Science Foundation, (NSB-04-07), 2004.

Government has primary responsibility for supporting higher education in science and technology at levels that allow the study of science or engineering and future careers in those fields to be competitively attractive with other fields.” The NSF’s substantial investment in the IGERT program and the decision to increase the annual IGERT trainee stipend to \$27,500 in 2003, and to \$30,000 for awards based on the 2004 Program Solicitation (NSF 04-550), reflects this effort to make graduate study in the sciences and engineering more competitive with other career options open to the brightest American students.

There are two main dissenting voices from this analysis of scientific workforce challenges. One questions the accuracy of the pipeline and workforce assessments cited above; the other suggests that, viewing education as the supply side of the equation and workplace conditions as the demand side, the more effective solutions focus on the workplace, or demand side, of the equation.

Those who question pipeline statistics¹³ point, as a possible parallel, to the mid-1980s NSF warning that the nation would soon lack enough scientists to maintain the professoriate, “a forecast that turned out to be wildly inaccurate.” They point out that, while the *Science Indicators 2004* does show fewer earned doctorates and fewer visas issued to foreign students, NSF and American Chemical Society statistics also show more Americans earning bachelor’s degrees in science and engineering, increased graduate enrollment as of 2002,¹⁴ and increased unemployment, at least among chemists, in 2002 and 2003. NSF also reports that 76 percent of international students getting PhDs in the U.S. intend to stay within the country, up from 63 percent a decade ago.

The demand-side argument is described by Zumeta and Raveling,¹⁵ who list three disincentives for students choosing advanced science education: (1) training and apprenticeship times are very long, ten years or more; (2) compensation for graduate and postdoctoral appointees, often in their mid-thirties, are very modest for professionals of that age; and (3) graduates’ prospects for an autonomous research position in academe or elsewhere are “uncertain and increasingly slim.” These authors, taking a policy perspective, see it as “critical to recognize that the research and teaching most scientists do has an important public good element, meaning that society as a whole benefits in ways not fully valued in market signals such as compensation levels.” They point out that policies have traditionally focused on the supply side of the equation – an effort that, even were it to succeed, would lead to “the unappealing postdoctoral logjam pattern that is now common in the life sciences.” Instead, the authors suggest federal support for a modest number of selective research assistant professorships at universities as a demand-side effort to improve the situation.

Richard Freeman, a Harvard University economics professor, points out that students and postdoctoral associates, especially from foreign countries, make up the academic science engine’s corps of “cheap labor.” “It runs the system, and it runs it very efficiently, in terms of the taxpayer.”¹⁶

¹³ Monastersky, R. “Is there a Science Crisis? Maybe Not,” *The Chronicle of Higher Education* (<http://chronicle/weekly/v50/i44/44a01001.htm>) July 9, 2004.

¹⁴ Monastersky quotes NSF as follows: “Overall, the declines in total graduate S&E enrollment from 1994 through 1998 have reversed with gains in enrollment every year since 1999.”

¹⁵ Zumeta, W. & Raveling, J. S. “Attracting the Best and the Brightest,” *Issues in Science & Technology*, January 10, 2003.

¹⁶ Monastersky, R. “Is there a Science Crisis? Maybe Not,” *The Chronicle of Higher Education* (<http://chronicle/weekly/v50/i44/44a01001.htm>) July 9, 2004, p.7.

The vested interest of academe in keeping the numbers of graduate students and postdoctoral associates high, regardless of career options for graduates, leads some to be skeptical of forecasts of undersupply.

Warren Washington, Chairman of the National Science Board, says professors in departments have the responsibility to ask themselves “Are they generating too many students? Or are they generating students who haven’t got the skills to apply for the jobs out there?”¹⁷ This returns us full circle to questioning how universities are training graduate students, and what skills they gain to apply to jobs outside of academe – an issue at the core of IGERT’s program goals.

Summary

The IGERT program was developed to meet the changing needs of society with regards to graduate education in STEM fields. Its objectives and program components reflect various calls for reform, specifically increasing the versatility (and therefore career options) of Ph.D. graduates, encouraging interdisciplinary work, and producing doctoral graduates who used their scholarship and creativity to address the needs of society. In funding IGERT programs the NSF aims not just to alter the educational pathways of doctoral students, but also to reshape the culture of higher education towards these ends. Chapter 2 of this report describes the methodology of the current study, an evaluation of IGERT’s impact. The remaining chapters present findings related to the IGERT program’s achievement of these goals, and its impact to date on students, faculty, and institutions.

¹⁷ Monastersky, R. “Is there a Science Crisis? Maybe Not,” *The Chronicle of Higher Education* (<http://chronicle/weekly/v50/i44/44a01001.htm>) July 9, 2004, p.8.