EVALUATION OF THE INITIAL IMPACTS OF THE NATIONAL SCIENCE FOUNDATION'S INTEGRATIVE GRADUATE EDUCATION AND RESEARCH TRAINEESHIP PROGRAM

Final Report

Prepared for:

The National Science Foundation
Directorate for Education and Human Resources
Division of Research, Evaluation, and Communication
and
Division of Graduate Education

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Executive Summary

This report summarizes findings from an evaluation of the impacts of the National Science Foundation's (NSF) Integrative Graduate Education and Research Traineeships (IGERT) program. Through support of interdisciplinary graduate education programs in Science, Technology, Engineering, and Mathematics, the IGERT program aims to educate U.S. Ph.D. scientists and engineers 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. IGERT also aims to catalyze a cultural change in graduate education by establishing innovative models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries. The IGERT program strives to facilitate diversity in student participation and preparation, thus contributing to the development of a diverse, globally-engaged, science and engineering workforce.[i]

A program evaluation conducted by Abt Associates Inc. examined IGERT program impacts on recruitment, students, faculty, and institutions, using surveys and interviews with IGERT participants and a comparison group of non-IGERT individuals. IGERT participants were drawn from a sample of participating departments in projects funded in 1998, 1999, or 2000. The comparison sample consisted of departments identified by IGERT department chairs as peer departments with whom they competed for graduate students. This enabled the construction of a comparison group that accounted for academic quality and provided a match for every IGERT department included in the study. Surveys were sent to IGERT PIs, department chairs, faculty and doctoral students, and to non-IGERT department chairs, faculty, and doctoral students. Resulting sample sizes were large enough to produce a level of precision such that proportions estimated from the full sample would have confidence intervals of plus or minus five percentage points or less. Survey response rates ranged between 72 and 94 percent. To provide data on institutional contexts, university administrators from IGERT and non-IGERT institutions were interviewed.

Overall, the study found that the IGERT program has had a measurable impact in altering the graduate educational experiences of participating students, supporting faculty engagement in interdisciplinary teaching and research, and advancing interdisciplinary graduate education within host institutions. Detailed findings related to the program goals of educating students, catalyzing cultural change, and promoting diversity are outlined below.

Educating Ph.D. Scientists and Engineers

NSF expects that IGERT projects will educate students to work in an interdisciplinary environment while being well grounded with depth of knowledge in a major field. The IGERT graduate experience should contribute to the professional and personal development of students and equip them to understand and integrate scientific, technical, business, social, ethical, and policy issues to confront the challenging problems of the future. Students should receive experience relevant to both academic and nonacademic careers, and be encouraged in developing an international perspective.

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

IGERT projects have successfully developed new educational experiences for students in all of these areas. IGERT students receive more extensive interdisciplinary training than non-IGERT peers, but maintain depth of study in their chosen fields. IGERT students consistently report greater opportunities to learn about other disciplines, interact with faculty and students from other disciplines, and work on projects involving multiple disciplines. They are better prepared to work in multidisciplinary teams and communicate with people outside their own fields. At the same time, according to both faculty and students, the level of in-depth preparation in students' fields is similar for IGERT and non-IGERT participants.

The IGERT experience provides students with significantly broader professional and personal skills for their future careers. IGERT students receive greater training in teamwork, presentation, and communication skills, and are twice as likely as non-IGERT students to have received formal training in research ethics, an area emphasized by the IGERT program. Participation in the IGERT program provides broader career exposure as well, with IGERT students reporting more opportunities to conduct off-campus internships and interact with people outside their home institutions and outside academia. Overall, the educational experiences reported by IGERT students are quite different from those reported by non-IGERT students, and as a result, IGERT students report feeling better prepared for their future professions, as measured by the data collected, than non-IGERT students.

Catalyzing a Cultural Change in Graduate Education

A longer-term goal for the IGERT program is to catalyze a cultural change in graduate education, resulting in faculty and institutional support for interdisciplinary graduate education. IGERT has been successful in promoting a fertile environment for faculty to engage in interdisciplinary teaching and research. While interdisciplinary activities are common among all faculty surveyed, IGERT faculty and department chairs report an additional shift towards more interdisciplinary work as a result of IGERT participation. IGERT faculty members team-teach with colleagues outside their departments and mentor graduate students from other disciplines in greater frequencies than non-IGERT faculty members. A majority of IGERT faculty members report that participating in IGERT has enabled them to teach a greater variety of students and incorporate a broader range of topics in courses. With respect to interdisciplinary research, more IGERT faculty publish and present research in journals and conferences from outside their home disciplines, and are more likely to work on research projects and co-author publications with colleagues from other disciplines.

According to the IGERT faculty respondents, participating in the program has been a stimulating professional experience, one to which they are willing to devote substantial time with little direct compensation while generally maintaining other departmental responsibilities. Large majorities of the faculty members feel that IGERT enabled them to establish work with colleagues in other departments and exposed them to new ideas. About half of the faculty members reported learning new research techniques, exploring research that would not otherwise be funded, or being in a better position to win new grants as a result of IGERT. These outcomes suggest important benefits for faculty participating in IGERT that have the potential to increase support for interdisciplinary approaches to graduate education.

Findings from the evaluation suggest that IGERT projects are helping advance interdisciplinary graduate education in their institutions. Project PIs report that their projects have led to policy changes for interdisciplinary coursework and teaching, revised degree requirements, and created new degrees and certificates, as well as increased university support for interdisciplinary education in

general. Participating department chairs point to IGERT grants as stimulating the development of new courses, and to a lesser extent, new degrees and requirements for doctoral students. Additionally, faculty members and department chairs perceive stronger departmental and institutional support for interdisciplinary research and education at IGERT institutions than non-IGERT institutions, though support for interdisciplinary education overall is modest compared with interdisciplinary research.

These reported institutional impacts vary across projects and may appear to be small within the scope of universities, but they are an indication that IGERT is catalyzing changes in graduate education via a funding mechanism that primarily supports graduate students. PIs are confident that they will be able to maintain some project benefits beyond the funding period, especially access to disciplines and expertise outside of students' home departments, and opportunities to study multiple disciplines. Many PIs and administrators report that other departments or programs at their home institutions have already adopted IGERT program elements.

Facilitating Diversity

IGERT projects have had a clear impact on the ability of participating programs to recruit, in the perception of faculty, more and better academically qualified individuals, and have the potential to increase the number of United States citizens currently enrolled in STEM doctoral programs. IGERT PIs and faculty members report successfully recruiting high quality students, including those students for whom the availability of an IGERT program was a factor in choosing to attend graduate school. IGERT projects provide an interdisciplinary alternative to what might otherwise be available to students, and IGERT students are more likely to pursue interdisciplinary education than their non-IGERT counterparts. The IGERT program has recruited minorities and women in science and engineering programs at rates equal to national averages. While IGERT projects have shown success in their recruitment efforts, the goal of the IGERT program is to be a leader in increasing diversity, and this challenge will continue to be a major focus of the program. The continued recruitment efforts of individual IGERT projects may in the future further increase the diversity of students enrolling in IGERT projects in these areas.

Conclusion

This evaluation finds that doctoral students participating in IGERT projects receive different educational experiences than non-IGERT students enrolled in single disciplinary degree programs, and that the IGERT program has been successful in achieving its goal of improving graduate educational programs in science and engineering. In various ways it has also begun to achieve its goal of catalyzing a cultural change in American graduate education, both by providing interested faculty members with an organized way to engage in interdisciplinary activity, and in developing alternate models of education that have been – and will likely continue to be – adopted by programs within IGERT host institutions. IGERT graduates enter the work force better prepared for the science of the future in the careers of the future.

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]

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[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."

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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 **programmatic 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 million[9] 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.

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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 statistics[13] 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]

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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 graduates 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.

Chapter 2: Evaluation Methodology

Previous Monitoring and Evaluation

Abt Associates has been evaluating for the National Science Foundation (NSF) various facets of the IGERT program since shortly after the program's inception in 1997. Monitoring initially focused on the characteristics of projects at individual universities, and consisted of analyses of data from a web-based Distance Monitoring System completed annually by the project Principal Investigators (PIs), funded trainees, and other students participating in the project.[18] The Web-based survey and resultant database provide descriptive information about each IGERT project (e.g., who participates in the project, how many trainees are funded and for how long, what are the structural elements of the program).

Beginning in 2002, NSF funded a cross-site analysis of the IGERT program, focusing on project implementation and early impacts. Under this work, Abt Associates conducted monitoring site visits with projects in the 1998, 1999, and 2000 cohorts, visiting each project in its third year of implementation. Site visits consisted of face-to-face interviews of PIs, trainees, and key faculty, as well as relevant department, school, and university administrators. Two or three relevant content area scientists also visited each project. These peer scientists, selected from each project's subject area, evaluated the scientific merit of project elements and experiences.

Information from the Distance Monitoring System combined with that collected during site visits has enabled Abt Associates and NSF to develop an in-depth understanding of the implementation of the IGERT program, along with its perceived successes and challenges encountered. The Distance Monitoring System has provided prescribed and consistent data across all IGERT sites, while individual site visits have allowed the collection of site-specific, in-depth information that answers questions raised by the Web-based collection and extends its scope. Together, the two approaches have provided as complete a portrait as possible of the evaluated program.

The IGERT Impacts Evaluation

Neither of the evaluation approaches described above, however, has enabled NSF to draw comparative conclusions about the impact of the IGERT program as compared with other, non-IGERT experiences. Thus in 2003, NSF contracted with Abt Associates to conduct an *Evaluation of the IGERT Program's Initial Impacts* for participating students, faculty, and institutions, employing a comparison group of non-IGERT individuals. The Impacts Evaluation, which forms the basis of this report, examines differences between groups of individuals – for example, the interdisciplinary nature of IGERT faculty compared with non-IGERT faculty, or the interdisciplinary training of IGERT students compared with non-IGERT students. The Impacts Evaluation also collected information on the degree to which IGERT projects have affected change within their institutions, and the institutional factors that support or hinder such change. The key difference between this study and the evaluation work that preceded it lies in its use of a comparison group to examine program impacts.

[18] The IGERT Distance Monitoring Web System is maintained by QRC Macro under separate contract.

Evaluation Questions

The principal objective of the evaluation is to determine the IGERT program's impact on participating students, faculty, and institutions. The primary research questions are outlined below:

Student indicators

- How does an IGERT education differ from that received in a traditional single disciplinary program?
- What is the perceived added value for students of IGERT related educational experiences?

Faculty indicators

- How do IGERT faculty differ from non-IGERT faculty in terms of their teaching, research, mentoring, networking, and productivity?
- How does participation in IGERT impact faculty teaching, research, mentoring, networking, and productivity?
- What is the perceived added value for faculty of participating in IGERT?

Institutional indicators

- How have IGERT projects influenced institutional culture and support for interdisciplinary graduate education?
- How have IGERT projects impacted institutional policies and procedures?
- How have IGERT projects impacted institutional structures?
- What elements of IGERT projects have been institutionalized or adopted by other institutional programs?

Recruitment indicators

- What is the added recruitment value of the IGERT project?
- What are the characteristics of students being recruited into IGERT programs, and how do they differ from traditional graduate students?

Sampling Methods

IGERT Sample

In order to allow projects adequate time to implement activities prior to the evaluation, we focused on the first three cohorts of the program. Fifty-two[19] of the 57 IGERT projects funded between 1998 and 2000 participated in the Impacts Evaluation. As many IGERT projects are collaborations of individuals from numerous departments (in some cases, ten or more), we included in the study the

[19] Five IGERT projects were not included in the study. One was excluded because its structure did not fit the sampling framework of the study: it draws individual students and faculty from a number of different universities, instead of from within one or two institutions. Four other projects declined to participate.

two largest departments from each IGERT project, as measured by the number of IGERT students enrolled.[20]

Comparison Group – Non-IGERT Sample

Once the IGERT sample of departments was identified, a comparison group could be constructed. Several possible comparison groups were considered for this study. First considered was a simple random sample of all non-IGERT institutions in the United States. While this would be nationally representative of non-IGERT sites, it would not take into consideration the quality characteristics of institutions housing the IGERT projects. It is likely that IGERT-funded institutions differ from non-funded institutions along various dimensions (size, types of degrees offered, level of research funding). A random national sample would not address variations in program implementation and quality associated with specific fields of study, or the variety of disciplines included in IGERT projects.

The second possibility considered was to compare IGERT participants to individuals participating in other interdisciplinary graduate programs, either national efforts or specific programs at individual institutions. As there is no organized record of interdisciplinary programs, this method would have first involved an initial review of educational programs across the country to identify appropriate programs. Moreover, while a comparison of IGERT with other interdisciplinary programs would illustrate IGERT's effectiveness in achieving desired interdisciplinary outcomes, it would not address the question of what is gained (or lost) from offering students an interdisciplinary component to their education, as compared with the traditional disciplinary model. It also would not account for general movement in science towards interdisciplinary work. As the latter were questions of primary interest to NSF, this option was rejected.

The third comparison option, which was the one selected for this study, was to compare IGERT participants to individuals from an appropriate set of traditional departmental graduate programs. This method contrasts the IGERT interdisciplinary experience with single department options otherwise available to students. The comparison is *interdisciplinary* against *single department* education, with IGERT as the exemplar of interdisciplinary. Any tendency for scientists in their particular field to be engaging in joint work with other disciplines simply as a matter of overall changes in the research field, and, consequently, in graduate education, is taken into account through the use of this comparison group. The limitation of this choice is that the comparison group may be flawed by selection bias; it is possible that both the character of the IGERT program and the outcomes for participants are more the result of their inherent tendency to seek interdisciplinary interactions than they are the effect of IGERT funding. This limitation was partially addressed by collecting data from non-IGERT sample individuals on the interdisciplinary nature of their education and research.

It was important that the selection of a comparison group account for the academic quality of the doctoral programs involved. We considered various methods of matching IGERT projects against traditional departments. Institutional and departmental data is available on several measures from the Integrated Postsecondary Education Data System, collected by the National Center for Educational

[20] Two of the IGERT programs have doctoral students housed in an interdisciplinary doctoral program: Bioinformatics and Neuroscience, which are not considered departments at their institutions. In these cases we looked at the two departments housing the greatest numbers of IGERT faculty members.

Statistics. Such data provides no indication of program quality, however. The Carnegie classifications are useful for grouping institutions, but are not specific to individual disciplines. The National Research Council (NRC) periodically ranks doctoral programs, but at the time of the study the latest rankings came from 1995, meaning that we would have been selecting comparisons based on the academic standing of departments nearly ten years earlier. Upon examination we also realized that because the NRC only ranked the top[21] institutions in each category, some of our IGERT departments were not ranked. Other IGERT departments were so new that their relevant fields (e.g., microelectronics, bioinformatics) did not even appear as a rankings category.

To enable the construction of a comparison group that accounted for academic quality and provided a match for all departments in our IGERT sample, we chose to use self-identified peer departments for the IGERT departments. We contacted the department chairs of the selected IGERT departments and asked them to identify for us the departments and institutions with whom they primarily compete for doctoral students. Of the list provided by each chair, we eliminated any programs that were involved with other IGERT projects, then selected the comparison department with characteristics most closely matching the desired IGERT department on the following institutional characteristics: control (public/private), geographic region, number of doctoral degrees granted, number of students enrolled full-time and part-time, and overall number of degrees granted).[22]

Using self-identified peers as a comparison group provides a reasonable approximation of academic quality, if one assumes that departments will compete for students of similar academic ability. The possible bias in this comparison comes from the tendency of academics to identify as their peers individuals or programs which, on other measures, may actually rank slightly higher than themselves (in other words, to self-inflate the comparison). Given the lack of other alternatives, we chose to accept this comparison group, with the understanding that this selection bias may have set a more difficult standard for assessing program impacts.

Department chairs from selected comparison institutions were approached and asked to participate.[23] Once IGERT and comparison departments were identified and recruited into the study, we drew from each a random sample of faculty members and graduate students. Comparison faculty and students were selected in equal proportions to the number of individuals included from each matched IGERT department, to ensure equal distribution across disciplines in both samples. Students must have completed at least two years of coursework, to ensure comparable levels of experience. We also asked chairs to identify the name of a university administrator who could speak to the university's position on interdisciplinary graduate education, as well as the contact information of any doctoral students who graduated from the program between September 2000 and December 2002. The selected administrators were interviewed to learn more about the institutional context in which IGERT projects were operating, and the graduates were sent a pilot graduates survey.

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[21] The 1995 NRC assessment of 41 fields of doctoral study included between 25 and 193 programs, depending on the discipline.

[22] Institutional data was obtained from the U.S. Department of Education's Integrated Postsecondary Education Data System (IPEDS).

[23] Very few department chairs declined to participate. If chairs could not be reached, we investigated whether faculty and student e-mail addresses were available through departmental websites instead. If chairs refused, or if contact information was not available via the web, an alternate comparison department was substituted.

Final Sample Sizes

Exhibit 2.1 shows our final sample size for the IGERT and Non-IGERT samples.

Exhibit 2.1

Final Sample Sizes

Respondent Type	IGERT Respondents	Non-IGERT Respondents [a]
Students	361	749
Faculty	390	773
Department Chairs	97	82
PIs	52	--
University Administrators	32	25

[a] Non-IGERT students and faculty were over-sampled to ensure adequate representation to draw statistically significant conclusions about differences between IGERT and Non-IGERT responses.

Data Collection Instruments

The 2004 Initial Impacts surveys were administered in the fall of 2004 and spring 2005 as web-based surveys, as follows:

1. Students (IGERT and Non-IGERT)
2. Faculty (IGERT and Non-IGERT)
3. Department chairs (IGERT and Non-IGERT)
4. IGERT PIs

Staff conducted telephone interviews with administrators at IGERT and non-IGERT institutions. Finally, a bibliometric analysis was conducted of CVs of our faculty sample (IGERT and Non-IGERT). A full report on the bibliometric analysis is included as an appendix at the end of this report.

Response Rates and Sample Characteristics

The final sample for the study was comprised of students, faculty, department chairs and PIs from 52 IGERT projects and, as described above, a carefully constructed comparison sample of non-IGERT students, faculty and department chairs. Resulting sample sizes were large enough to produce a level of precision such that proportions estimated from the full sample would have confidence intervals of plus or minus five percentage points or less. Exhibit 2.2 presents the sample size for each category of respondents and their response rates.

Exhibit 2.2

Final Sample Size and Response Rates for Web-Based and Email Surveys

Respondent Type	IGERT Respondents			Comparison Non-IGERT Respondents		
	N Sent Out	N of Completes	Response Rate[a]	N Sent Out	N of Completes	Response Rate[a]
Web Surveys						
Students	361	306	85%	749	566	76%
Faculty	390	347	89	773	556[b]	72
Department Chairs	97	85	88	82	59	72
PIs	52	49	94	--	--	--
Telephone Interviews						
University Administrators	32	24	75%	25	16	64%

[a] Response rates calculated on the basis of number of fully and partially completed surveys.

[b] 580 comparison faculty (75% response rate) completed the survey. Of these, 24 faculty reported participating in an IGERT project. Number of completes calculated after eliminating the 24 surveys.

Sample Characteristics

The respondents included in the final IGERT and non-IGERT samples share similar characteristics. Departments included in the study are roughly equivalent in size, having comparable numbers of faculty members and doctoral students (Exhibit 2.3).

Exhibit 2.3

Size of IGERT and Non-IGERT Departments

Number of faculty members	IGERT (N=85)	Non-IGERT (N=59)
Median	28	24
Minimum	8	8
Maximum	150	67
Number of doctoral students	**IGERT (N=81)[a]**	**Non-IGERT (N=58)[a]**
Median	68	70
Minimum	8	6
Maximum	250	320

[a] Four IGERT and one Non-IGERT department chair respondents did not respond to this item.

Note: We have reported the median number of faculty and students rather than the average in order to account for the few respondents who come from institutions where academic departments are housed in larger units.

Source: Initial Impacts Survey of Department Chairs 2004.

Questions: "Approximately how many faculty are in your department? Approximately how many doctoral students are currently enrolled in your department?"

The resulting IGERT and non-IGERT samples are also equivalent in disciplinary spread, as portrayed in Exhibit 2.4. Much of the IGERT sample is divided among Engineering (32 percent), Life Sciences (21 percent), and Physical Sciences (21 percent), and the non-IGERT group is distributed in similar proportions.

Exhibit 2.4

Discipline Distribution of IGERT and Non-IGERT Department Chairs, Faculty Members, and Students (Completed Surveys)

	Department Chairs		Faculty		Students	
	IGERT (N=81)	Non-IGERT (N=59)	IGERT (N=337)	Non-IGERT (N=556)	IGERT (N=306)	Non-IGERT (N=566)
Engineering	32%	34%	36%	34%	32%	33%
Life Sciences	21	14	24	21	21	24
Physical Sciences	21	27	17	20	17	17
Social Sciences	7	5	7	7	12	8
Computer Sciences	9	10	5	9	6	6
Environmental Sciences	7	2	5	5	7	5
Mathematical Sciences	1	5	3	3	3	4
Psychology	1	3	3	2	3	2

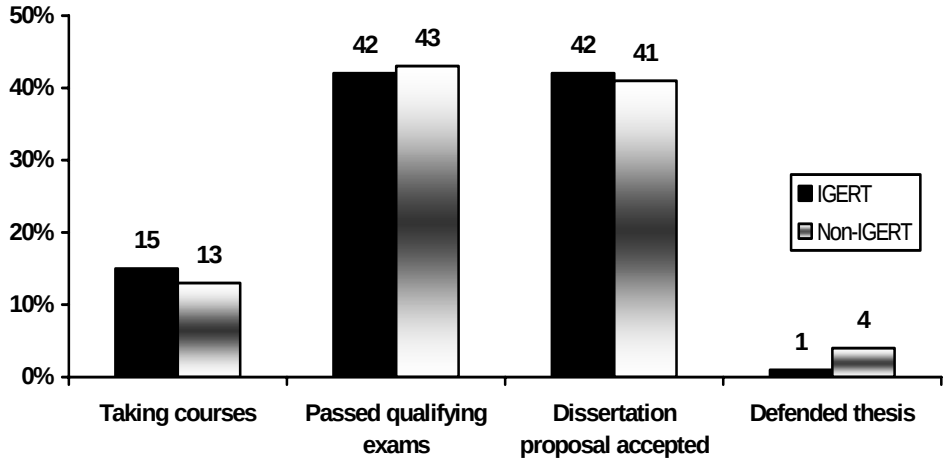
Source: Sample Characteristics of Department Chairs, Faculty, and Students based on the sample file for respondents who completed their surveys.

Finally, the IGERT and non-IGERT students who responded to the survey are very similar in program status and prior background. The survey sample included students who were at least two years into their program, to allow time for sufficient programmatic experiences. Less than one third of the students had entered their doctoral program with a prior post-undergraduate degree (24 percent IGERT; 31 percent non-IGERT).[24] At the time of reporting most of the students had passed their qualifying examinations and were working on their dissertation research (Exhibit 2.5). The percentage of students at various levels in their programs does not vary for the IGERT or non-IGERT groups, validating comparisons of their reported experiences to date in their graduate programs later in this report.

[24] There is a significant difference among the non-IGERT students depending on nationality: 19 percent of the United States students had a prior degree, compared with 50 percent of foreign non-IGERT students.

Exhibit 2.5

Program Status of IGERT and Non-IGERT Students at Time of Survey



IGERT N= 306. Non-IGERT N= 566. Percents do not sum to 100 due to rounding.

Sources: Initial Impacts Survey of Students 2004.

Question: "What is your current status in your graduate program?"

A Note about International Students

All IGERT trainees must be United States citizens or permanent residents. The non-IGERT comparison student sample, however, includes both American and foreign students. Just under two-thirds of the non-IGERT sample are United States citizens (58 percent) or permanent residents (3 percent). The remaining students are foreign nationals (37 percent) or did not report their citizenship (2 percent). Analyses were conducted to examine the difference between native and foreign non-IGERT students. In most cases, there were not significant differences between the groups. Where there were differences, this has been noted in the text. Foreign or non-reported citizenship individuals are also reported separately from the American non-IGERT individuals throughout this report in places where citizenship might be related to the responses (such as in reporting on race and ethnic background, other programs applied to, or international experiences). Otherwise, all non-IGERT students are reported together for data describing their general graduate program experiences (courses taken, research conducted) and levels of preparedness.

Prevalence of IGERT Projects in Comparison Institutions

Constructing a comparison sample of academically equivalent departments for the IGERT-involved departments while avoiding departments involved in other IGERT projects was a challenging task, given the prevalence of IGERT grants in research universities (See Exhibit 2.6). IGERT institutions in 2005 comprise 46 percent of all institutions in the Doctoral/Research University-Extensive Carnegie institutional classifications.

Exhibit 2.6

Prevalence of IGERT Grants Among Institutions in Research and Doctoral Carnegie Classifications

Carnegie Ranking	Number of Institutions with an IGERT Grant	Number of Institutions without an IGERT Grant	Total Number of Institutions in Classification	Percent of Overall Institutions with an IGERT Grant
Doctoral/Research Universities – Extensive	69	82	151	45.7%
Doctoral/Research Universities – Intensive	7	103	110	6.4
Master's Colleges and Universities I	1	494	495	0.2

Notes: Data represents eight cohorts of IGERT projects, funded between 1998 and 2005

Source: The 2000 Carnegie Classifications.

Doctoral/Research Universities—Extensive: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the doctorate. During the period studied, they awarded 50 or more doctoral degrees per year across at least 15 disciplines.

Doctoral/Research Universities—Intensive: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the doctorate. During the period studied, they awarded at least ten doctoral degrees per year across three or more disciplines, or at least 20 doctoral degrees per year overall.

Master's Colleges and Universities I: These institutions typically offer a wide range of baccalaureate programs, and they are committed to graduate education through the master's degree. During the period studied, they awarded 40 or more master's degrees per year across three or more disciplines.

Due to the prevalence of IGERT projects on college campuses, it was inevitable that some departments included in the comparison sample came from institutions that also housed IGERT grants. Institutions in the final comparison sample were split as follows: 67 percent have an IGERT grant; 33 percent do not. This does not mean that the specific comparison departments selected were involved with IGERT projects – it only means that somewhere else on campus other departments have received an IGERT grant. We confirmed with comparison department chairs at the time of sampling that to their knowledge none of their faculty members were involved with an IGERT project. To verify the chair's information, all comparison faculty were asked whether they were participating in an IGERT grant, and comparison faculty who stated they were directly involved with IGERT were eliminated from our sample. This resulted in four percent of the comparison faculty who completed the survey (N=24) being eliminated from the analysis.

Analysis Techniques

Several types of tests were used to measure significant differences between the IGERT and non-IGERT respondents. The chi square test, which measures significant differences of patterns of frequency, was used on frequency tables for categorical variables. Because the chi square test rejects small Ns, we used the Fisher's exact test in place of the chi square when we had a low cell count or empty cells. For example, this test was used for variables that had five point scales. We used the t-

test, which measures the significant difference between means of continuous variables, for those questions where the respondent could write in any number, i.e. number of publications.

Organization of This Report

We have organized this report along the primary goals of the IGERT program as laid out in Chapter 1. Chapter 3 explores the program's goal of educating new U.S. Ph.D. scientists and engineers for the careers of the future, and looks at the impacts of IGERT on participating students. Chapters 4 and 5 describe the ways in which IGERT projects are catalyzing cultural change for faculty (Chapter 4) and institutions (Chapter 5). Chapter 6 examines the success of the IGERT program in increasing participation of individuals from diverse backgrounds. Chapter 7 summarizes evaluation findings and suggests areas for future study. Appendix A presents supplementary data tables from the study, and Appendix B contains the full text of the report summarizing the faculty bibliometric analysis. Unless otherwise noted, all data presented in this report come from the surveys of the Impacts Evaluation. The next chapter explores the educational experiences of IGERT and non-IGERT students, and draws conclusions about the impact of IGERT participation to date for enrolled students.

Chapter 3: Impacts on Students

This chapter examines the IGERT program's success in meeting its goal of educating the scientists and engineers of the future 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. We explore ways in which IGERT students are gaining interdisciplinary perspectives; developing research skills; receiving professional training in areas such as working in teams and communication; developing an international perspective; and being prepared for a wide range of careers. This chapter addresses the following research questions:

- How does an IGERT education differ from that received in a traditional single disciplinary program?

- What is the perceived added value for students of IGERT related educational experiences?

The IGERT Model of Education

The IGERT model of graduate education for doctoral students as laid out in the program solicitation[25] has five components (emphasis added):

- The IGERT project should be organized around an **interdisciplinary theme** involving a diverse group of faculty members, which provides a framework for **integrating research and education** and for promoting collaborative efforts within and across departments and institutions.

- Students should gain the **breadth of skills**, strengths, and understanding to work in an interdisciplinary environment while being **well grounded with depth of knowledge** in a major field.

- Students should receive experience relevant to both **academic and nonacademic careers**. This may involve such activities as internships and mentoring in industrial, national laboratory, academic, or other settings.

- Globalization of research and career opportunities places importance on providing students with an **international perspective**. This may be gained through programs within the institution, or through strongly integrated, collaborative research experiences and/or fieldwork at foreign institutions and sites.

- The graduate experience should contribute to the **professional and personal development** of the students and equip them to understand and integrate scientific, technical, business, social, ethical, and policy issues to confront the challenging problems of the future.

[25] IGERT Program Solicitation NSF 05-517.

Individual grantees exercise considerable latitude in organizing their own IGERT projects within specific institutional contexts to achieve these program goals. This chapter presents evidence that IGERT projects are addressing the program elements outlined above.

Interdisciplinary Experiences

The words "interdisciplinary" and "multidisciplinary" are often used interchangeably to refer to work completed at the intersection or boundary of multiple fields. Indeed, the first two IGERT program solicitations referred to "multidisciplinary" research and education, after which the solicitation language was changed to use the word "interdisciplinary." Reflecting this usage, we use the term interdisciplinary graduate education in this report[26] to refer to the wide range of activities in which IGERT participants engage, which might include:

- education pursued by an individual in multiple disciplines, where each discipline is taught by educators situated in single disciplines but the disciplines are not necessarily related to each other;

- education involving issues that can only be studied by integrating parts of existing disciplines into a new discipline; or

- education involving issues that require individuals to have substantial knowledge of multiple disciplines.[27]

IGERT projects have adopted different interpretations of what it means to organize graduate education around an interdisciplinary theme. One fifth of the PIs (22 percent) expect their students to become experts in more than one field. More report that students in their projects will have mastery of one field and be able to work with scientists in other fields (63 percent), and/or that they are educating students who know and can use the techniques of multiple disciplines (59 percent).[28] Reflecting this usage, we use the term interdisciplinary graduate education in this report[29] to refer to the wide range of activities in which IGERT participants engage.

The first program component outlined above states that in organizing around an interdisciplinary theme, projects are to involve faculty and students from diverse disciplinary backgrounds in an environment in which research and education are integrated, and which allows students to develop the ability to work in an interdisciplinary environment, while maintaining depth in their own field. By

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[26] The term "multidisciplinary" is used in this report in a few cases where question items were worded accordingly.

[27] Adopted from: Kockelmans, Joseph. "Why Interdisciplinary?" *Interdisciplinarity and Higher Education*. University Park: The Pennsylvania State University Press, 1979, 123-160.

[28] Initial Impacts Survey of PIs 2004. PIs were asked the degree to which each statement described the goals of their IGERT projects, on a five-point scale from "Not at all" to "Completely." Reporting here the percent that chose "Completely" for each of three separate items. Percents do not sum to 100 because these are separate items.

[29] The term "multidisciplinary" is used in this report in a few cases where question items were worded accordingly.

exposing students to individuals, methods, and tools from multiple disciplines, NSF intends that IGERT projects will produce doctoral graduates more capable of conducting interdisciplinary research.

To address these goals, IGERT projects fund trainees from a variety of disciplines, provide instruction by faculty from multiple disciplines, allow trainees to participate in research with faculty from multiple disciplines, and/or offer courses that draw on multiple disciplinary fields.[30]

These departures from traditional doctoral education organization result in broadened experiences for IGERT students (Exhibit 3.1). Nearly all IGERT students report having access to disciplines and expertise outside of their home department, compared with only two thirds of non-IGERT students. IGERT students are also significantly more likely than non-IGERT students to report having opportunities to study multiple disciplines, or to have taken courses that exposed them to the laboratories or research techniques of multiple disciplines. Outside the classroom, significantly more IGERT students than non-IGERT students report that they have worked on research projects involving multiple disciplines, rotated through laboratories in multiple disciplines or attended a professional conference outside their home discipline. And while one-quarter of IGERT students report having participated in the development or teaching of any multidisciplinary/interdisciplinary course, or in any other multidisciplinary/interdisciplinary educational effort, only one-eighth of non-IGERT students have done the same.[31]

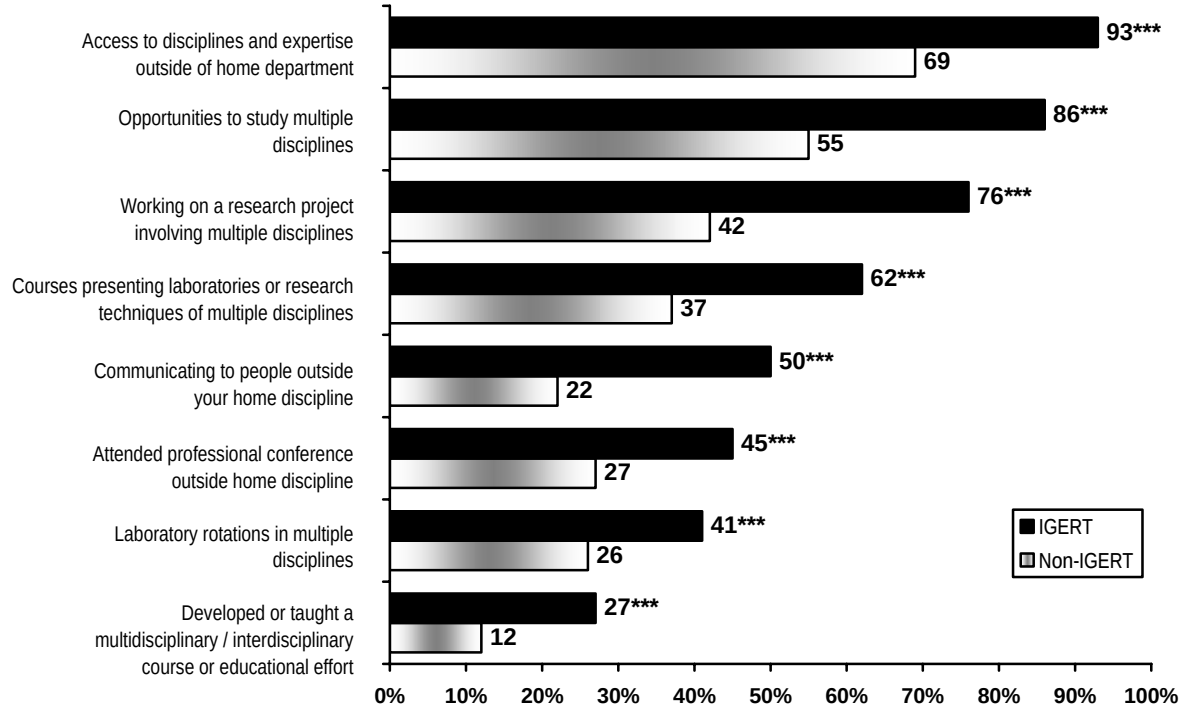
IGERT projects often prepare students for cross-discipline communication with "bridge" courses, targeted courses designed to bring individuals quickly up to speed in disciplines outside their own field. Thus IGERT students (61 percent) are twice as likely as non-IGERT students (29 percent) to report that they have taken courses to learn background content knowledge outside their own field ($p<.0001$).

[30] IGERT Distance Monitoring Web System, 2003: Survey of PIs.

[31] All differences are significant at the $p<.0001$ level.

Exhibit 3.1

Interdisciplinary Educational Experiences of IGERT and Non-IGERT Students



IGERT N ranges from 303-306. Non-IGERT N ranges from 559-566. Range is due to missing responses.

Significance denoted as: *** (p < .0001)

Source: *Initial Impacts Survey of Students 2004.*

Questions: "Which of the following benefits or opportunities have you received as part of your graduate program?" "Have the following interactions been part of your graduate program?" "Have the following research experiences been part of your graduate training?" "Have you ever attended a professional conference in a field outside your home discipline?"

Interdisciplinary Interactions

Part of the interdisciplinary experience of IGERT students comes from interactions with students and faculty members from other disciplines. Most of the PIs (82 percent) indicated that their projects provide students with opportunities to interact with faculty members in other disciplines in ways that are not available to other students. As a result, as shown in Exhibit 3.2, IGERT students report more opportunities to interact with faculty members in other departments than do their non-IGERT counterparts. IGERT students have also worked significantly more with faculty from other universities, and with public or government laboratory scientists (see Exhibit 3.4). It is thus not surprising that about four-fifths of IGERT students (83 percent) but only slightly more than half (57 percent) of non-IGERT students report that they have developed the ability to communicate with and work on research problems with researchers from more than one discipline.

Exhibit 3.2

Percent of IGERT and Non-IGERT Students Reporting They Have Worked with Faculty from Their Own or Different Departments on Research Projects During Their Graduate Program

I have worked with…	IGERT (N=306)	Non-IGERT (N=566)
Faculty at my institution in my home department/ academic unit	98%	94%
Faculty at my institution in other departments/academic units	71	50 ***

Significance denoted as: *** ($p < .0001$)

Source: Initial Impacts Survey of Students 2004.

Question: "With which of the following types of people have you worked on research projects while in your current graduate program? Check all that apply."

Interaction with multiple faculty members is formalized by many projects through requirements regarding dissertation advisors. More IGERT students than non-IGERT students report they have multiple formal advisors (56 versus 31 percent, $p<.0001$), and IGERT students are twice as likely as non-IGERT students to have a faculty member advisor from a department other than their own home discipline (48 versus 22 percent, $p<.0001$).

In addition to working with faculty, IGERT students also report working with students from multiple disciplines. Three quarters of the IGERT students (76 percent) have worked on a research project involving students from multiple disciplines, compared with only 42 percent of non-IGERT students ($p<.0001$). IGERT students are twice as likely as non-IGERT students to have worked on research projects with students with different disciplinary backgrounds (64 versus 36 percent, respectively, $p<.0001$).

IGERT students clearly receive more interdisciplinary experiences than non-IGERT students. Interestingly, 46 percent of non-IGERT students agreed with the statement that they wish they had received more exposure to other disciplines as part of their graduate program. Thus IGERT students are not the only individuals interested in interdisciplinary education, and differences between IGERT and non-IGERT students are not attributable solely to differing ambitions of the two.

Depth versus Breadth of Knowledge

The second IGERT program component calls for students to gain the breadth of skills, strengths, and understanding to work in an interdisciplinary environment while being well grounded with depth of knowledge in a major field. Interested stakeholders have sometimes wondered if participation in IGERT interdisciplinary graduate education decreases students' depth of knowledge in their chosen doctoral field,[32] but students in IGERT programs do not perceive such a problem. Equal numbers of IGERT and non-IGERT students agree with the statement that they are able to study their home field

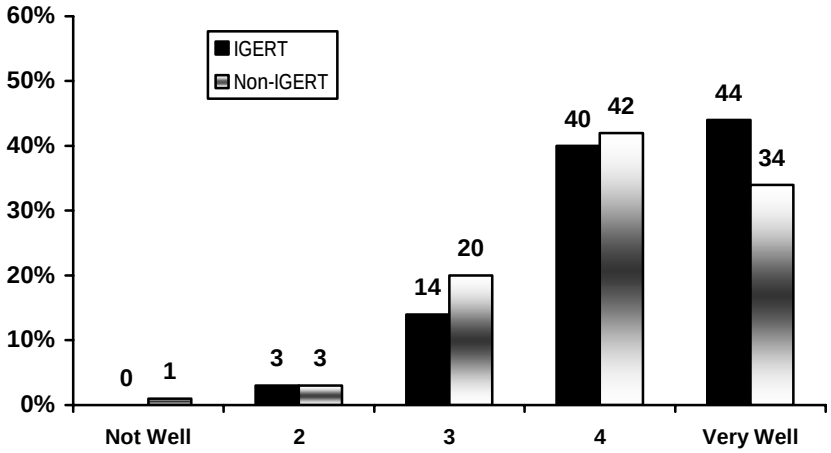
[32] The issue was raised, for example, at the 2005 meeting of IGERT Participants held in Washington D.C.

in as much depth as they would like (84 versus 82 percent, respectively), and that their program has well prepared them to know their own discipline in depth (80 versus 81 percent).[33]

It is possible that this observed equality of responses is due to IGERT students having different expectations of the level of depth they want to have in their chosen field compared to non-IGERT students, and that the level of depth achieved by IGERT students is actually lower than that achieved by non-IGERT students. Faculty data, however, do not indicate this to be the case. Only 21 percent of the PIs surveyed agreed[34] with the statement, "IGERT students lose some content expertise by spending time working across disciplines." Further, when faculty were asked how well they thought their students were being prepared to know their own discipline in depth, IGERT faculty described their IGERT students as similarly prepared to know their own discipline in depth as did non-IGERT faculty of their respective doctoral students (Exhibit 3.3).

Exhibit 3.3

Percent of IGERT and Non-IGERT Faculty Indicating That Their Students Are Prepared to Know Their Own Discipline in Depth



IGERT N = 339, Non-IGERT N = 546.

Note: Eight IGERT faculty and ten non-IGERT faculty indicated "N/A" for this item and were excluded from this chart.

Source: *Initial Impacts Survey of Faculty 2004.*

Question: "How well do you think that your [IGERT graduate students] [graduate students] are being prepared to know their own discipline in depth?."

[33] Reporting the percentage choosing 4 or 5 on a 5-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

[34] Reporting the percentage choosing 4 or 5 on a 5-point scale from 1 (Strongly Disagree) to 5 (Strongly Agree).

This agreement in faculty responses is not due to varying opinions of IGERT and non-IGERT faculty members on the importance of disciplinary depth of knowledge. Equal portions of both groups believe that it is "very important"[35] that students graduating with a Ph.D. in their field know their own discipline in depth (79 versus 81 percent, respectively). If one assumes that IGERT faculty and non-IGERT faculty share similar expectations of disciplinary depth of knowledge for doctoral students, then the consensus among most PIs, students, and faculty is that participation in IGERT does not decrease depth of knowledge in students' chosen doctoral field.

Preparation for Diverse Careers

The third component specified in the program solicitation states that IGERT students should receive experience relevant to both academic and nonacademic careers, and suggests that such training may include such activities as internships and mentoring in industrial, national laboratory, academic, or other settings. IGERT projects provide students with a variety of experiences that expose them to both academic and nonacademic careers, and IGERT students report feeling better prepared for a wider range of careers than do non-IGERT students. There are no observable differences between the two groups, however, in their career goals.

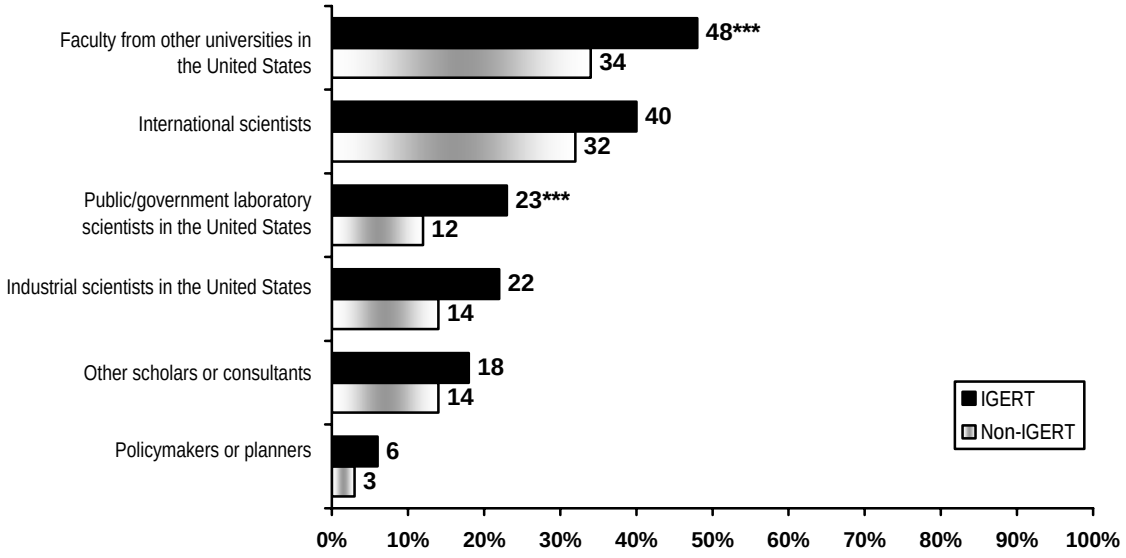
Exposure to Diverse Careers

One method of exposing students to different careers, both academic and non-academic, is to allow for opportunities for IGERT students to work on research projects with individuals from a range of occupations. IGERT projects vary in the extent to which such opportunities are provided. As a result of these opportunities, IGERT students are significantly more likely to report having worked with individuals from other universities or government laboratories in the U.S. (Exhibit 3.4). More IGERT students also reported working with international scientists, industrial scientists, and other individuals outside academia, but the difference was not significant compared to non-IGERT students.

[35] Reporting the percentage choosing '4' or '5' on a scale of 1 (Not important) to 5 (Very important).

Exhibit 3.4

Percent of IGERT and Non-IGERT Students Reporting They Have Worked With Various Individuals on Research Projects During Their Graduate Program



IGERT N=306. Non-IGERT N=566. Significance denoted as: *** ($p < .0001$)

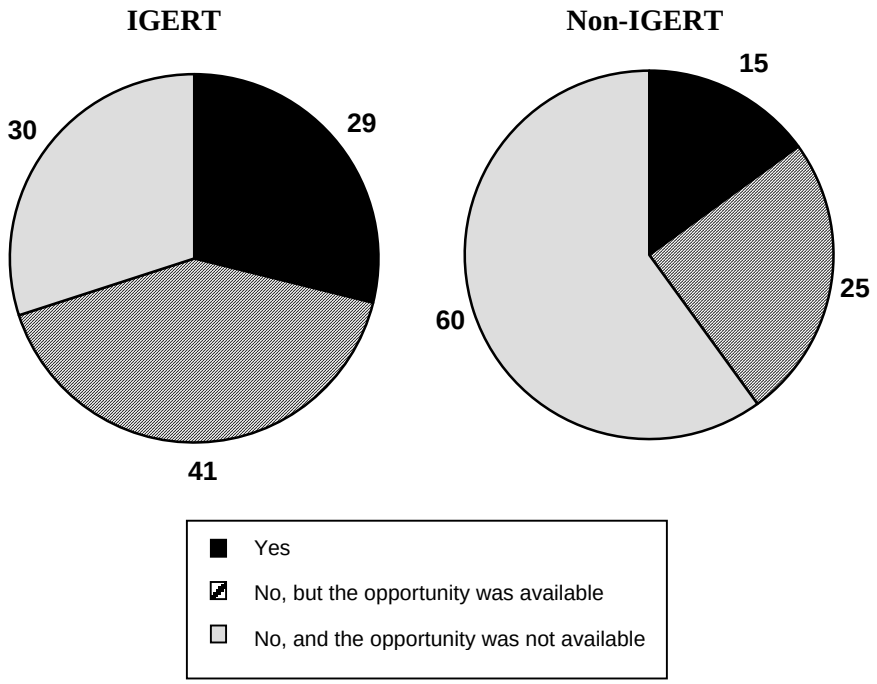
Source: *Initial Impacts Survey of Students 2004.*

Question: "With which of the following types of people have you worked on research projects while in your current graduate program? Check all that apply."

A second method of exposing students to different careers is to provide opportunities to conduct internships or work off campus in other environments. Eighty percent of PIs report that their projects provide opportunities for IGERT students to conduct research off campus that are not offered to other students. As a result, 71 percent of IGERT students, but only 47 percent of non-IGERT students, report they have had opportunities to conduct research, study, or work off-campus ($p<.0001$). As described in Chapter 2, most of the students in the sample have completed their coursework and are working on their dissertation, meaning it is likely that if they plan to conduct an internship while in graduate school they probably had already done so at the time of the survey. While a minority of both groups of students report having actually taken part in an internship lasting a month or more with private sector industries or businesses, public sector laboratories or agencies, or other organizations, twice as many IGERT students have done so (29 percent) as have non-IGERT students (15 percent). Site visit interviews conducted by Abt Associates with students revealed that many students did not want to conduct an extended internship because of the extra time involved, and felt that they had already gained many extra experiences as part of their IGERT participation. Student survey responses indicate that whether or not they conduct an internship, IGERT students are significantly more likely to have the opportunity available to do so than non-IGERT students – 70 versus 40 percent had internship opportunities available (Exhibit 3.5).

Exhibit 3.5

Percent of IGERT and Non-IGERT Students Reporting Opportunities to Conduct an Off-Campus Internship



IGERT N=306, Non-IGERT N=566.

Note: If "Yes" and "No, but the opportunity was available" are combined into one response indicating that the opportunity to conduct an internship was available, the difference between the IGERT students (70 percent) and non-IGERT students (40 percent) is statistically significant at p<.0001.

Source: *Initial Impacts Survey of Students 2004.*

Question: "Have you taken part in any internships lasting a month or more with private sector industries or businesses, with public sector laboratories or agencies, or in any other setting?"

Perceptions of Career Preparation

How well do students think they are being prepared for various careers? IGERT and non-IGERT students have varying perceptions of how well their programs are preparing them for a wide range of career possibilities. Nearly two-thirds (63 percent) of IGERT students agree with the statement that they are being prepared for a wide range of career possibilities. Fewer non-IGERT students (44 percent) feel the same way (p<.0001).

Similar proportions of IGERT and non-IGERT students report that their program is preparing them to understand and work in an academic setting (82 versus 78 percent)[36]. Students are far less likely to feel that their graduate program is well preparing them to work outside of academia (such as in

[36] Reporting the percent choosing 4 or 5 on a scale of 1 (Not well) to 5 (Very well) when asked "how well has your graduate program prepared you to…?"

industry). Still, 40 percent of IGERT students report such preparation, compared with 29 percent of non-IGERT students ($p<.001$).

Very few IGERT students are concerned that participating in an interdisciplinary program may harm their ability to get a traditional job in their own field (15 percent). Indeed, the pilot results from the survey of graduates suggest that IGERT graduates may have an easier time of finding a job than non-IGERT graduates: only 8 percent of IGERT graduates reported it was difficult to find their current job, compared with 25 percent of non-IGERT graduates.[37]

Students' Career Goals

Despite having received different opportunities and experiences, IGERT students and non-IGERT students report similar career goals (Exhibit 3.6). One third of all students are most interested in pursuing a faculty position at a research university, while another third want to obtain a research position either in industry or at an academically affiliated institute.

Pilot results from the graduate survey suggest slight[38] differences in the initial careers IGERT and non-IGERT students enter upon graduation. The most frequent positions held by the graduates, excluding postdoctoral positions, included faculty positions at research universities (43 percent IGERT, 39 percent non-IGERT); research positions in academic institutes (18 percent IGERT; 4 percent non-IGERT); and research positions in industry (14 percent IGERT; 26 percent non-IGERT).

Exhibit 3.6

Career Goals of IGERT and Non-IGERT Students

	IGERT (N=302) [a]	Non-IGERT (N=566)
Faculty position at a research university	32%	35%
Researcher in industry	23	25
Researcher in an academic or affiliated institute/center	14	14
Faculty position at any other college	11	14
Self-employment	6	4
Researcher in a public or private policy environment	4	2
Policymaker/Planner	3	1
Working in a nonprofit/foundation environment	2	2
Other	4	2

[a] Frequency missing = 4

Source: Initial Impacts Survey of Students 2004.

Question: 'Which <u>one</u> of the following careers are you most interested in pursuing after graduation?"

[37] Reporting the percent of graduates choosing 4 or 5 on a scale of 5 (Very difficult) to 1 (Not difficult at all) when asked, "How difficult was it to find your current job?" (IGERT N=38; non-IGERT N=28)

[38] Note that the sample size is small (37 IGERT; 29 non-IGERT) so that the significance of differences cannot be determined, and each individual response represents several percentage points.

Development of an International Perspective

Providing students with an international perspective is another area in which the IGERT program places emphasis, with the intent of preparing students for global research and career opportunities. The program solicitation states that an international perspective may be gained through programs within the institution, or through strongly integrated, collaborative research experiences and/or fieldwork at foreign institutions and sites. The IGERT program's emphasis on international experiences has varied with time, with selected projects receiving supplemental funding to support international activities. Thirty-three percent of the projects in the first three cohorts have received international supplements as of 2005.[39] The percentage of projects receiving this funding has increased during that time for those cohorts: 29 percent of the 1998 projects received a supplement, compared with 33 percent of the 1999 projects, and 37 percent of the 2000 projects.

International Experiences

Not all IGERT projects have activities in place explicitly aimed at furthering the international perspective of their students, despite the program expectation that they do so. Indeed, as of the 2004 web monitoring survey, 28 percent of the PIs indicated they had not yet begun to address this goal. While this percent was higher for PIs in newer cohorts, there were some PIs in each of the earlier cohorts who also indicated they have not begun addressing this goal, further suggesting that international activities are not part of all projects.[40]

Nonetheless, many IGERT programs have developed activities and requirements aimed at developing an international perspective in their students, including:

- working with international scientists in the U.S.;
- working with international scientists abroad (often through internships); and
- international travel or conference attendance.

Working with international scientists in the United States

Student collaboration with international scientists most frequently occurs when international scientists visit the United States to participate in research. There is some indication that IGERT students are more likely to have these experiences than non-IGERT students. Seventy-seven percent of IGERT students, and 66 percent of non-IGERT students, report they have worked within the United States with scientists of other nationalities ($p<.001$). Most students also report that during their graduate work they have communicated and worked with people of different cultures, nationalities, or backgrounds (87 percent IGERT; 79 percent non-IGERT). IGERT students at projects that have received supplemental international funding do not vary from IGERT students at projects without such funding on these items.

[39] Data from the IGERT Program Office, National Science Foundation.

[40] Percent of PIs indicating "Not Begun" when asked about the status of achieving the goal of "Developing Students' International Perspective," by cohort: 1998 (18%); 1999 (19%); 2000 (11%); 2001 (14%); 2002 (33%); 2003 (71%). 2004 Web Monitoring Survey of PIs.

Working with international scientists abroad

Fewer students (23 percent IGERT; 17 percent non-IGERT) report having worked with scientists of other nationalities in those scientists' home countries. In part this may be because only some projects offer such opportunities: 58 percent of PIs report that some of their trainees work with foreign scientists or engineers outside the U.S., and 14 percent have opportunities available for students to work with private companies abroad.[41] It appears that the international supplements are used to foster such opportunities, because IGERT students at projects with international supplemental funding are more likely to have worked abroad (31 percent) than IGERT students at projects without supplements (16 percent).

International travel and conference attendance

Significantly more IGERT students (87 percent) than non-IGERT students (66 percent) report that they receive opportunities for travel as part of their graduate program ($p < .0001$). This travel could be domestic or international, but when asked whether they had attended any international conferences within the past two years, 37 percent of IGERT versus 27 percent of non-IGERT students said they had done so. There is no difference in such attendance among non-IGERT students between domestic or foreign students.

International Perspective

IGERT students and non-IGERT students are equally likely to report that they are familiar with current research being conducted in their field in foreign countries (66 versus 68 percent, respectively), but as outlined above, they differ in the types of experiences they are afforded to interact or collaborate with international researchers. As a result, some IGERT students believe they are better prepared to collaborate with international scientists in the future. IGERT students (38 percent) are more likely to report feeling "very well prepared" to collaborate with international scientists than their non-IGERT counterparts (28 percent). IGERT students at projects where PIs indicated they have begun addressing this program goal are even more likely as well. These numbers are overall generally lower than other items, suggesting less emphasis on international training than other elements.

Professional Training

The final IGERT program component calls for the IGERT graduate experience to contribute to the professional and personal developments of students and equip them to understand and integrate scientific, technical, business, social, ethical, and policy issues to confront the challenging problems of the future. Professional training of IGERT students as examined in this study falls into three main areas: providing students with the research training they will need, preparing students to work in teams, and equipping them with the written and oral communication skills needed in a variety of settings.

Preparation to Conduct Research

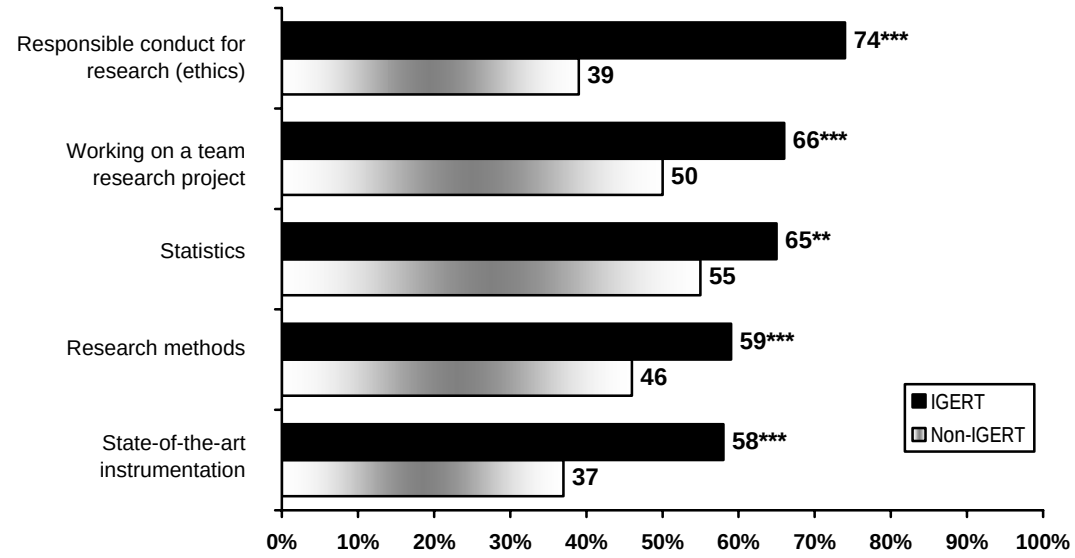
Many IGERT projects develop research experiences specifically for their IGERT students, which often involve courses on research methods, training in the ethical conduct of research, and access to cutting-edge technology or instrumentation. Sixty-seven percent of the PIs report, for example, that

[41] IGERT Distance Monitoring Web System, 2003.

their IGERT project offers IGERT students access to equipment that is not offered to other students. IGERT and non-IGERT students were asked whether they had taken courses or received formal training (workshops, seminars, retreats, etc.) in several research related areas, including research methods, statistics, ethics, and instrumentation. Overall IGERT students were significantly more likely to report such experiences than non-IGERT students, as shown in Exhibit 3.7. The greatest difference between the two groups was reported in training or coursework in the responsible conduct of research, suggesting that the IGERT program's encouragement for projects to provide students with training in research ethics has been influential. IGERT students were also significantly more likely to report receiving formal training or coursework in research methods, statistics, and state-of-the-art instrumentation.

Exhibit 3.7

Percent of IGERT and Non-IGERT Students Reporting Research-Related Training



IGERT N=306. Non-IGERT N=566.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: *Initial Impacts Survey of Students 2004.*

Question: 'Have you received formal training or taken courses in the following areas? 'Training' includes workshops, seminars, retreats, special sessions within a course, etc."

Do the extra research experiences reported by IGERT students lead to better preparation to conduct research? To some extent it appears so, at least with regards to the ethical conduct of research (Exhibit 3.8). While both IGERT and non-IGERT students report that their graduate program is well preparing them to conduct high quality research, IGERT students are significantly more likely to report that their graduate program is preparing them well to conduct research in an ethical manner (p<.0001).

Exhibit 3.8

How well is your graduate program preparing you to conduct research? (Percent of Students)

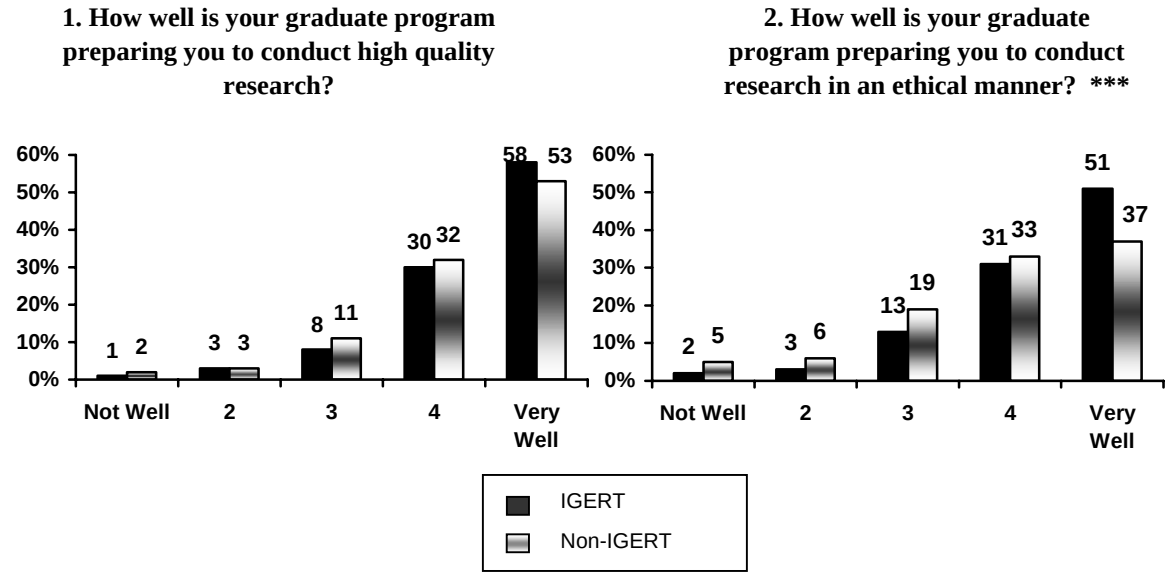


Chart 1: IGERT N=306. Non-IGERT N=565.
Chart 2: IGERT N=302. Non-IGERT N=542.

Note: Chart 1: One Non-IGERT individual responded N/A and has been excluded from these exhibits.
Chart 2: Four IGERT and twenty-four Non-IGERT individuals responded N/A and have been excluded from these exhibits.
Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: Initial Impacts Survey of Students 2004.

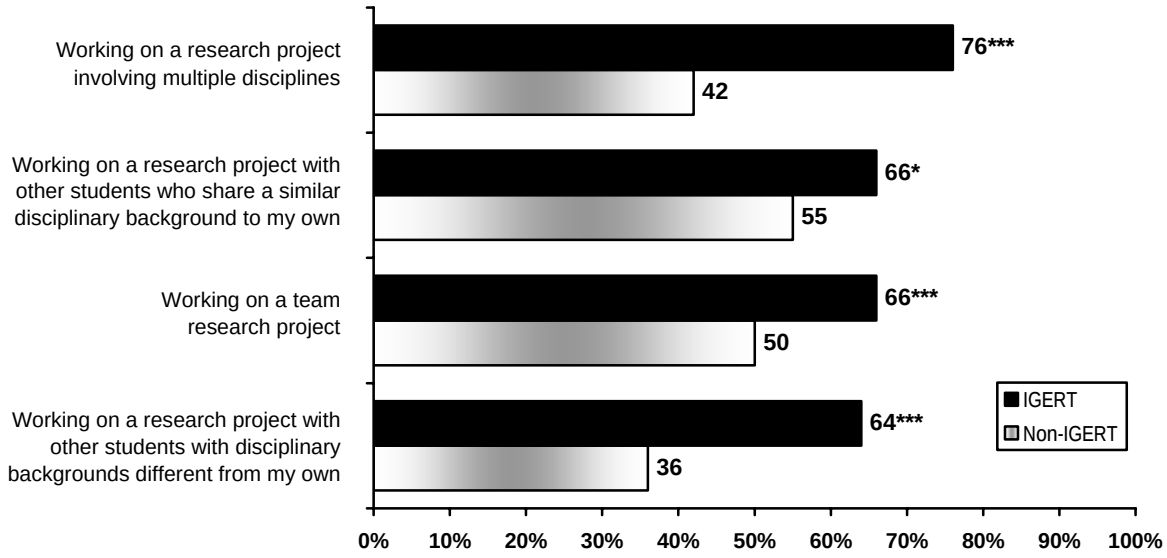
Question: On a scale of one to five, where one represents "Not Well" and five represents "Very Well" how well do you think your graduate program is preparing you for the following activities?

Preparation to Work in Teams

IGERT projects provide trainees opportunities to work in teams both within their own disciplines and with faculty members and students from other disciplines. Many projects require students to complete projects in multidisciplinary teams as part of their IGERT training. As a result, IGERT students are far more likely to report team research experiences than non-IGERT students, especially when those teams are multidisciplinary and involve students from other disciplines (Exhibit 3.9). Thus it is not surprising that IGERT students feel far better prepared to work in multidisciplinary teams in the future than do non-IGERT students, as shown in Exhibit 3.10 (p<.0001).

Exhibit 3.9

Teamwork Experiences Reported By IGERT and Non-IGERT Students



Notes: IGERT N=306. Non-IGERT N=566.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: Initial Impacts Survey of Students 2004.

Question: "Have the following research experiences been part of your graduate training?"

Exhibit 3.10

How well is your graduate program preparing you to work in teams? (IGERT and Non-IGERT students)

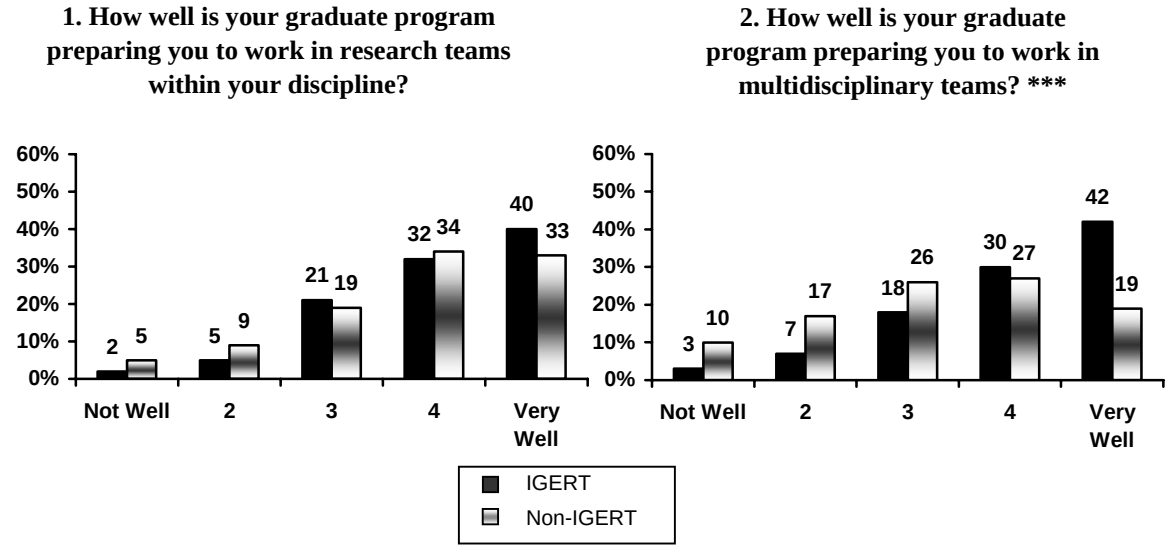


Chart 1: IGERT N=304. Non-IGERT N=559.
Chart 2: IGERT N=302. Non-IGERT N=546.

Notes: Several respondents choosing "N/A" were excluded:
Chart 1: IGERT (2), non-IGERT (7)
Chart 2: IGERT (4), non-IGERT (20). Percents may not sum to 100 due to rounding.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: *Initial Impacts Survey of Students 2004.*

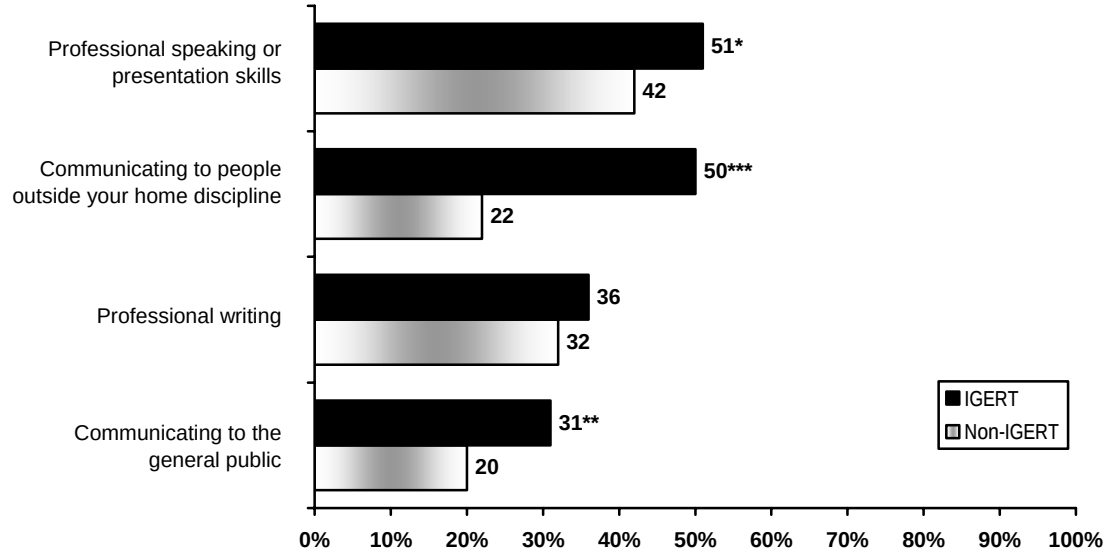
Question: "On a scale of one to five, where one represents 'Not Well' and five represents 'Very Well,' how well do you think your graduate program is preparing you for the following activities?"

Communication Skills

IGERT projects formally address the development of trainees' communication skills in various ways (written, oral) and with various audiences (scientists in their own field, scientists in other fields, non-scientists). Students also learn communication skills informally, through other activities (such as internships, working in teams, or working with other scientists). IGERT students are less likely to report having received formal training or coursework on communication strategies than they are some of the other activities reported elsewhere in this chapter. However, they are still more likely than non-IGERT students to report such communication oriented training, and significantly more likely to have received training in communicating to people outside their own discipline or to the general public (Exhibit 3.11).

Exhibit 3.11

Percent of IGERT and Non-IGERT Students Reporting Having Received Training or Coursework in Communication



IGERT N=306. Non-IGERT N=566.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

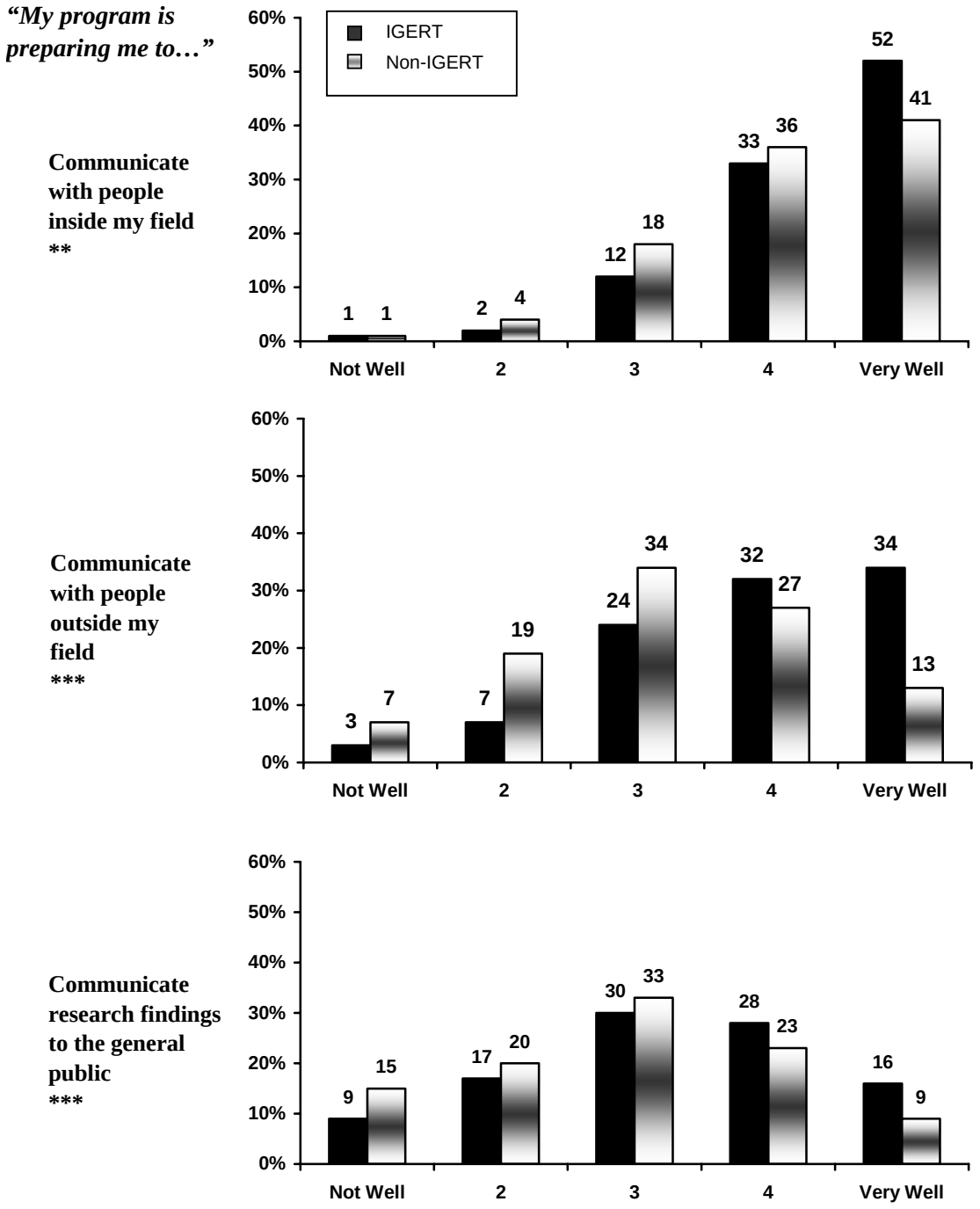
Source: *Initial Impacts Survey of Students 2004.*

Question: 'Have you received formal training or taken courses in the following areas? 'Training' includes workshops, seminars, retreats, special sessions within a course, etc."

As a result of these experiences, IGERT students feel somewhat more prepared than non-IGERT students to communicate with people inside of their field, and much more prepared to communicate with people outside their own field. They are somewhat more likely to feel prepared to communicate research findings to the general public (Exhibit 3.12).

Exhibit 3.12

Student Perceptions of How Well Their Program is Preparing Them to Communicate with Various Individuals



Ns vary due to exclusion of "N/A" responses as follows: Communicate with people inside my field: IGERT N=306. Non-IGERT N=565. Communicate with people outside my field: IGERT N=306. Non-IGERT N=563. Communicate research findings to the general public: IGERT N=302. Non-IGERT N=555.
Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: Initial Impacts Survey of Students 2004.

Question: "How well do you think your graduate program is preparing you for the following activities?"

Summary

IGERT projects have successfully developed new educational experiences for students in the areas emphasized in the program solicitation. IGERT students receive more extensive interdisciplinary training than non-IGERT peers, but maintain depth of study in their chosen fields. IGERT students consistently report greater opportunities to learn about other disciplines, interact with faculty and students from other disciplines, and work on projects involving multiple disciplines. They are better prepared to work in multidisciplinary teams and communicate with people outside their own fields. At the same time, according to both faculty and students, the level of in-depth preparation in students' fields is similar for IGERT and non-IGERT participants.

The IGERT experience provides students with significantly broader professional and personal skills for their future careers. IGERT students receive greater training in teamwork, presentation, and communication skills, and are twice as likely as non-IGERT students to have received formal training in research ethics, an area emphasized by the IGERT program. Participation in the IGERT program provides broader career exposure as well, with IGERT students reporting more opportunities to conduct off-campus internships and interact with people outside their home institutions and outside academia. Overall, the educational experiences reported by IGERT students are quite different from those reported by non-IGERT students, and as a result, IGERT students report feeling better prepared for their future professions, as measured by the data collected, than non-IGERT students. In the next chapter, we explore the impacts of the IGERT program on participating faculty members.

Chapter 4: Impacts on Faculty

The second goal of the IGERT program is to catalyze 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. Part of this cultural change involves fostering the development of interdisciplinary perspectives and collaborations among participating faculty members. This chapter focuses on the impacts of the IGERT program on the faculty participating in the program and examines ways in which they are engaging in interdisciplinary collaborations in their professional lives. In this chapter we discuss faculty involvement with the IGERT program and its perceived impact on their teaching, networking, mentoring, research and productivity in turn, and address the following research questions:

- How do IGERT faculty differ from non-IGERT faculty in terms of their teaching, research, mentoring, networking, and productivity?
- How does participation in IGERT impact faculty teaching, research, mentoring, networking, and productivity?
- What is the perceived added value for faculty of participating in IGERT?

Without having surveyed faculty prior to their participation in the IGERT program, we cannot know for certain if the faculty behaviors and characteristics observed are due to pre-existing interest of IGERT faculty in interdisciplinary work, to participation in the IGERT program, or to a combination of both factors. Most faculty (IGERT and non-IGERT) reported that they are engaged in some interdisciplinary work. We thus attempted in this analysis to identify ways in which IGERT participation might advance this type of work.

Faculty Characteristics

Drawn from departments that are comparable in size and disciplinary spread, at comparable institutions, the faculty in our IGERT and non-IGERT samples share similar time commitments. Both faculty participating in the IGERT program and their non-IGERT comparison group report that, on average, they spend about a third of their time on teaching, mentoring and advising students (33 and 34 percent respectively); just under half of their time on research (46 and 47 percent respectively); and the remaining time on related administrative tasks, such as serving on committees.

Faculty Participation in IGERT

A little over half of the faculty (55 percent) involved with the IGERT program joined their project in the year prior to or within the first two years of the award of their project and have remained involved ever since. Over two-thirds (71 percent) of the faculty involved with the IGERT program reported that they "experience at least some IGERT activities as a separate demand on their time."[42] Of these

[42] *Initial Impacts Survey of Faculty 2004*. "Do you experience at least some of your IGERT activities/responsibilities as work separate from your other research/teaching/service responsibilities in your home department?" IGERT faculty N=346.

faculty members, the majority (85 percent) spend up to a quarter of their time on IGERT–related work, which is over and above their research, teaching and other service responsibilities in their home departments. Nine-tenths of the IGERT faculty have over time either maintained their initial level of participation in the program (41 percent) or become more heavily involved with the program (47 percent) indicating a strong level of interest in the program. IGERT faculty responsibilities range from advising graduate students to project management (Exhibit 4.1).

Exhibit 4.1

Ways in which Faculty Participate in the IGERT Program

	IGERT (N=245)
I advise IGERT graduate students	89%
I serve on IGERT dissertation committees	83
I conduct IGERT-related research	77
I attend IGERT workshops or lectures	76
IGERT graduate students work in my lab	73
I teach IGERT courses	65
I contribute to IGERT project management	45

Note: Question was presented only to faculty members who responded to yes to the previous question, "Do you experience at least some of your IGERT activities/responsibilities as work separate from your other research/teaching/service responsibilities in your home department?"

Source: Initial Impacts Survey of IGERT Faculty 2004.

Question: "In what ways do you participate in the IGERT project?"

Despite the commitment of time and responsibilities over and above their departmental activities, IGERT faculty report that their participation in the IGERT program has not altered the amount of time they spend on departmental activities. Most say they spend equal time on such activities as teaching departmental courses, advising students, and engaging in departmental leadership activities, as they did before they got involved with the program (Exhibit 4.2). The one exception to this is research. While two-thirds of the faculty report spending the same amount of time conducting research with other faculty in the department as before, 21 percent report that they are now spending **more** time on such research, suggesting that IGERT projects stimulate research activities among faculty members in participating departments.

IGERT department chairs concur that participation in IGERT does not interfere with faculty members' departmental obligations. Most selected '1' (56 percent) or '2' (26 percent) on a scale of 1 ("Not at all") to 5 ("Extensively") when asked to what extent they think participation in the IGERT grant interferes with faculty members' ability to meet their non-IGERT departmental responsibilities. None selected 5 ("Extensively") and 81 percent reported that they did not think participation in the IGERT grant had "drawn time and attention of faculty away from the department."[43] In addition, most IGERT faculty report support for their work from their departmental colleagues, with only 19

[43] Initial Impacts Survey of Department Chairs 2004.

percent reporting that their department colleagues resent the time they spend on IGERT related activities.

Exhibit 4.2

Changes in Time Spent on Departmental Activities as a Result of IGERT Participation

	Percent of IGERT Faculty (N=244)		
	Less Time	Equal Time	More Time
Teaching department courses	13%	84%	3%
Advising department students	10	81	9
Engaged in department leadership activities	14	74	12
Conducting research with other departmental faculty	12	66	21

Notes: One respondent did not answer the question.

Question was presented only to faculty members who responded to yes to the previous question, "Do you experience at least some of your IGERT activities/responsibilities as work separate from your other research/teaching/service responsibilities in your home department?"

Source: Initial Impacts Survey of IGERT Faculty 2004.

Question: "Please indicate whether your IGERT participation has resulted in your spending less time, equal time, or more time on each of the non-IGERT responsibilities listed below."

The IGERT program provides little to no monetary benefit to the faculty. Whatever benefits of participation in this program accrue to the faculty are thus gained through interactions with students and collaboration with colleagues. Despite the fact that participation in the program is an add-on to their already busy academic lives, faculty both participate in the program and stay involved for long periods of time. Over time many faculty members' participation in the program has increased. These findings suggest that faculty members perceive benefit from participating in the IGERT program.

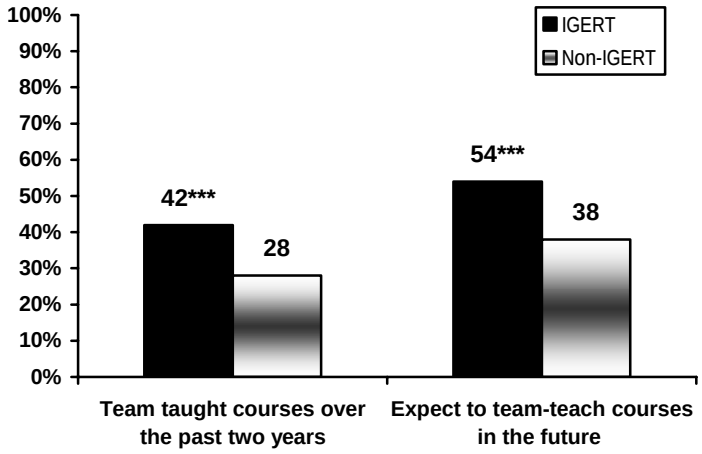
Impact on Teaching

Team Teaching

IGERT and non-IGERT faculty members share similar teaching loads, on average teaching two or three courses each year. However, IGERT faculty are significantly ($p<.0001$) more likely to team-teach with faculty members from other disciplines than non-IGERT faculty members, suggesting a stronger interest in team-teaching as well as the opportunity to do so. Site visit data suggests that IGERT projects may provide some of these team-teaching opportunities. Forty-two percent of the IGERT faculty have, over the past two years, team-taught a course with faculty members from outside their home discipline as compared with 28 percent of non-IGERT faculty. The proportion of faculty members who expect to team-teach courses in the future is also significantly higher for the IGERT faculty as compared with their non-IGERT counterparts (54 versus 38 percent, $p<.0001$) (Exhibit 4.3).

Exhibit 4.3

Percent of IGERT and Non-IGERT Faculty Who Have Team Taught with Faculty Members Outside Their Home Department, or Plan to in the Future



IGERT N=346. Non-IGERT N=556.
Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: Initial Impacts Survey of Faculty 2004.

Questions: "Have you team-taught any courses in the last two years with faculty member(s) outside your home department?" (yes, no) and *"How likely do you think it is that you will team-teach courses in the future with faculty members from departments outside your own department?" Response Scale: 1 ("Not likely") to 5 ("Very likely"). Reporting the percentage who selected either '4' or '5'.*

Interdisciplinary Teaching

IGERT faculty report that their participation in IGERT has directly impacted the interdisciplinary nature of their teaching and working with students. As a result of their participation in the IGERT program, two-thirds of the IGERT faculty (67 percent) believe that they are able to work with a greater variety of students, and 53 percent report that IGERT has resulted in their addressing a broader range of topics and incorporating readings from other fields in their teaching. As a result of participating in IGERT, close to half of the IGERT faculty (53 percent) report that they are more likely to consider team-teaching with faculty members outside their own department.[44]

Impact on Interdisciplinary Networks

Participation in IGERT has expanded faculty members' interdisciplinary networks. Close to three-quarters (72 percent) of the faculty participating in the IGERT program report that their participation in the program has enabled them to work with faculty in other departments whom they would

[44] Based on all those who selected the response options 4 and 5 on a five-point scale ranging from "1=strongly disagree" to "5=strongly agree."

otherwise not have met, and 77 percent say that being a part of this program has enabled them to get exposure to new ideas outside their area of knowledge.[45]

Impact on Mentoring Students

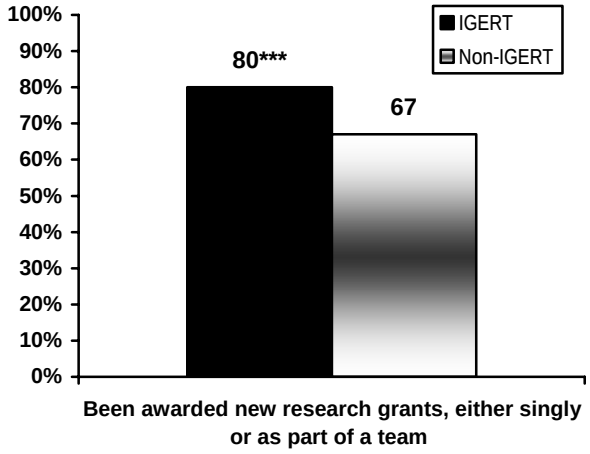
In addition to expanding their networks by working with faculty from other disciplines, IGERT faculty members have had the opportunity to work with a greater variety of students. Both IGERT and non-IGERT faculty report mentoring graduate students outside their own disciplines, on average between 2 and 3 such students. A significantly greater proportion of IGERT faculty (67 percent, p<.0001) report mentoring graduate students outside their home discipline than non-IGERT faculty (47 percent), suggesting that faculty participating in the IGERT program are more likely to expand their interactions with students in other disciplines.

Impact on Research

Both IGERT and non-IGERT faculty are engaged in research related activities, spending a little less than half their time on research. Working singly or in teams, both IGERT and non-IGERT faculty report that they have been awarded new research grants. This is significantly more so for the IGERT faculty (80 percent) than non-IGERT faculty (67 percent) (Exhibit 4.4).

Exhibit 4.4

Percent of IGERT and Non-IGERT Faculty Awarded New Research Grants in the Last Two Years



IGERT N=345. Non-IGERT N=554.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: *Initial Impacts Survey of Faculty 2004.*

Question: "Have you engaged in any of the following research activities in the last two years? …Been awarded new research grants, either singly or as part of a team."

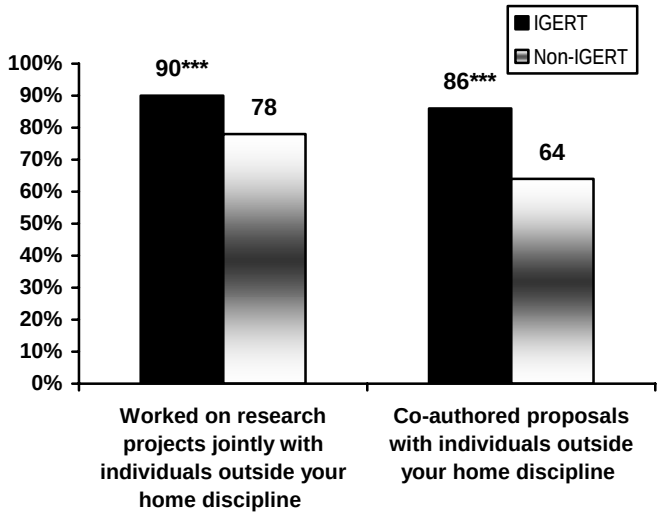
[45] Based on those who selected the response options 4 and 5 on a five-point scale ranging from "1=strongly disagree" to "5=strongly agree."

Interdisciplinary Research

Virtually all of the IGERT faculty (99 percent) and most of the non-IGERT (89 percent) faculty reported that they consider part of their research to be interdisciplinary. While many non-IGERT faculty report that they are engaged in interdisciplinary research activities, IGERT faculty are significantly more likely to do so. Both IGERT and non-IGERT faculty have worked on research projects (90 versus 78 percent), and have written research proposals with individuals outside their own disciplines (86 and 64 percent respectively), but the number of IGERT faculty reporting these activities is significantly higher than that of the non-IGERT faculty (Exhibit 4.5).

Exhibit 4.5

Percent of IGERT and Non-IGERT Faculty Engaged in Interdisciplinary Research Activities



IGERT N=346. Non-IGERT N=556.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: *Initial Impacts Survey of Faculty 2004.*

Question: *"Have you engaged in any of the following research activities in the last two years?"*

Impact on Faculty Productivity

Publications and presentations are two indicators of faculty productivity. It might be expected that as faculty get more exposure to interdisciplinary research either through IGERT or in general in their home institutions, it will be reflected in their work. We discuss below data obtained from survey questions asking the faculty where and with whom they publish and present their research, and from a bibliometric analysis of faculty publications and citations as listed in their *curriculum vitae*. (The complete bibliometric analysis report is included in Appendix B).

In the last two years IGERT faculty have produced more multi/interdisciplinary publications than non-IGERT faculty. The proportion of faculty who have co-authored books and articles with colleagues from other disciplines in the last two years is significantly higher for IGERT as compared

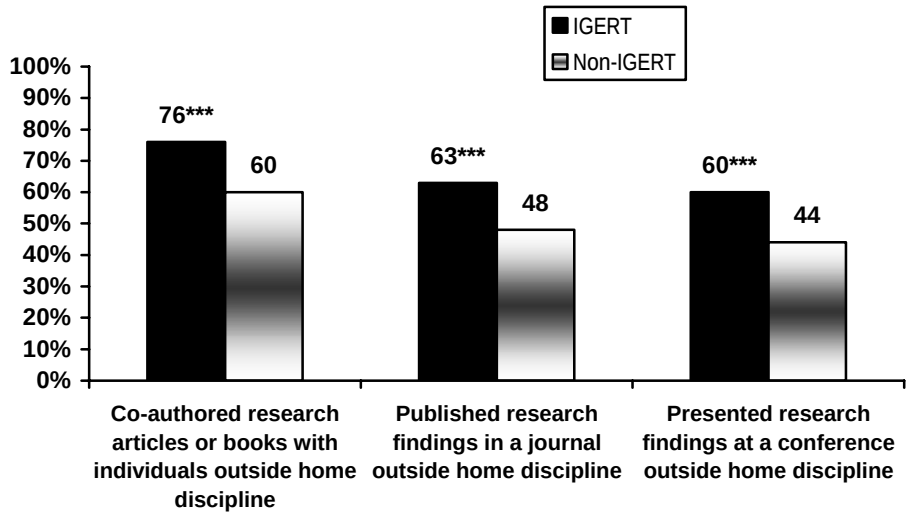
with non-IGERT faculty (76 and 60 percent respectively) (Exhibit 4.6). The number of such co-authored books is roughly the same for both groups: IGERT faculty have on average co-authored 5 such books and articles in the last two years, as compared with non-IGERT faculty (4 books and articles).[46]

The impact of interdisciplinary work is visible in the publications and presentations made by both the IGERT and non-IGERT faculty. Both IGERT and non-IGERT faculty members reported that they have presented the results of their research at conferences outside their home discipline, but IGERT faculty are one and a half times more likely than non-IGERT faculty to do so. Over the past two years IGERT faculty have made an average of 4.5 presentations at conferences outside of their home discipline, each as compared with the average of 3.5 presentations for the non-IGERT faculty.[47]

Although the median number of articles published (2.0) was the same for both groups, a significantly larger proportion of IGERT faculty (63 percent compared with 48 percent) report that they have published their research findings in journals outside their home disciplines.

Exhibit 4.6

Interdisciplinary Publications and Presentations by IGERT and Non-IGERT Faculty



IGERT N ranges from 344-346. Non-IGERT N ranges from 551-555. Range is due to missing responses.

Significance denoted as: * (p<.01) ** (p<.001) *** (p<.0001)

Source: *Initial Impacts Survey of Faculty 2004.*

Question: "Have you engaged in any of the following research activities in the last two years?"

[46] Initial Impacts Survey of Faculty 2004.

[47] Ibid.

Data from the **bibliometric analysis** of faculty publications and citations supports the survey data on faculty productivity and provides some additional indicators of the inter/multidisciplinary nature of the faculty publications. *Curriculum Vitae* for all faculty members were analyzed and publications for the last five years 1999-2003 were included in the analysis. Both IGERT and non-IGERT faculty were equally prolific in their writing and publications (with an average of 8.5 and 8.9 papers per author respectively over 5 years). A majority of both IGERT and non-IGERT faculty (approximately 85 percent of each group) publish books, articles and papers both in and outside their own disciplines, but IGERT faculty are slightly more likely to publish out of field. Overall, 54 percent of all IGERT publications were published outside the author's discipline compared with 50 percent of all non-IGERT publications. In certain disciplines such as Biology, Psychology, Mathematics and the Humanities, IGERT faculty were much more likely to publish out of field than non-IGERT faculty.[48]

IGERT faculty are more frequently cited than their non-IGERT counterparts, with an average of 16 citations per paper as compared with 12 citations per paper for the non-IGERT group, and this is true for all disciplines except the social sciences. The more frequent citations may indicate that the IGERT authors generally have a higher scientific impact than others, but this difference may be unrelated to participation in IGERT. Both the IGERT as well as the non-IGERT faculty reference materials outside their own disciplines. Overall, 60 percent of all references used by IGERT authors and 55 percent of all references listed by non-IGERT faculty are to fields outside their own disciplines. IGERT faculty in Biology, Psychology, Mathematics and the humanities are more likely to reference authors out of field than non-IGERT faculty. Another measure of collaboration and cooperation among authors is co-authorship. As reported earlier, a significantly larger proportion of IGERT faculty have coauthored books and articles as compared with non-IGERT faculty, but the number of people they collaborate with on each of their publications is about the same for both the IGERT and non-IGERT faculty.

Perceived Added Value of Participating in IGERT

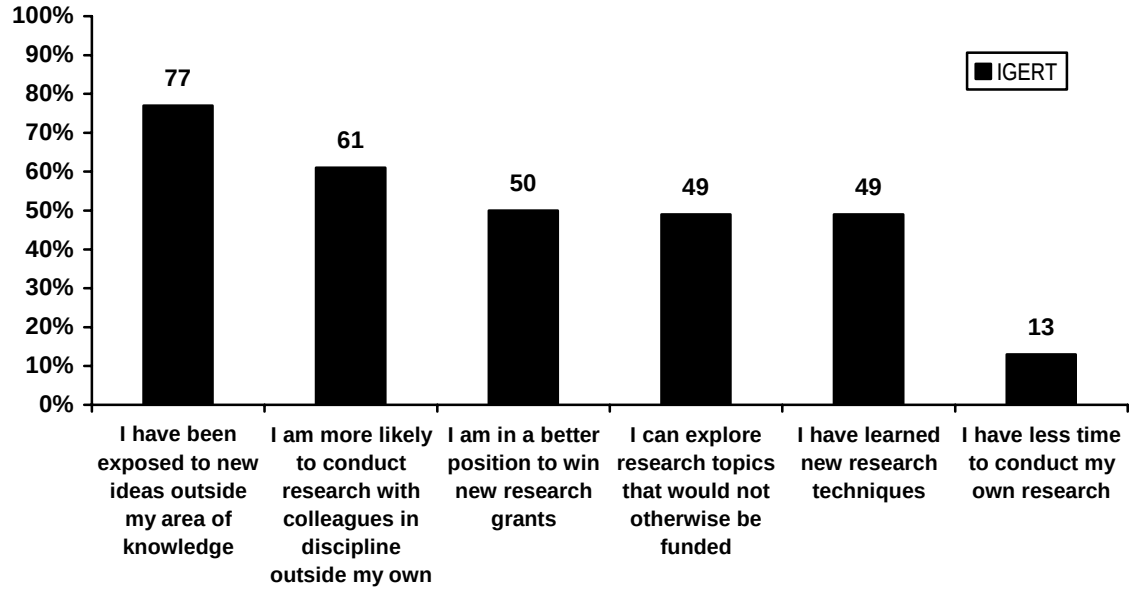
IGERT faculty members report that participation in the IGERT program has enhanced their own interdisciplinary opportunities. A little over three quarters of the IGERT faculty report that as a result of participation in IGERT they have been exposed to new ideas outside their area of knowledge. Close to half have learned new research techniques (49 percent) and are more likely to collaborate with colleagues outside their own disciplines (61 percent) (Exhibit 4.7). In addition, they believe that as a consequence of their IGERT participation they can explore new research topics that may otherwise not be funded, and that they are in a better position to win new research grants. Very few faculty report that participation in IGERT takes time away from their own research.

[48] *Bibliometric Analysis Report*: Appendix B.

Exhibit 4.7

Impact of Participation in the IGERT Program on Faculty Research

"As a result of participating in IGERT…"



IGERT N=344. Two respondents did not complete this question.

Note: Reporting the percentage who selected the response options 4 and 5 on a five-point scale ranging from "1=strongly disagree" to "5=strongly agree."

Source: Initial Impacts Survey of Faculty 2004.

Question: "To what extent do you agree or disagree with the following statements about the impact that participating in the IGERT project has had on your professional life?"

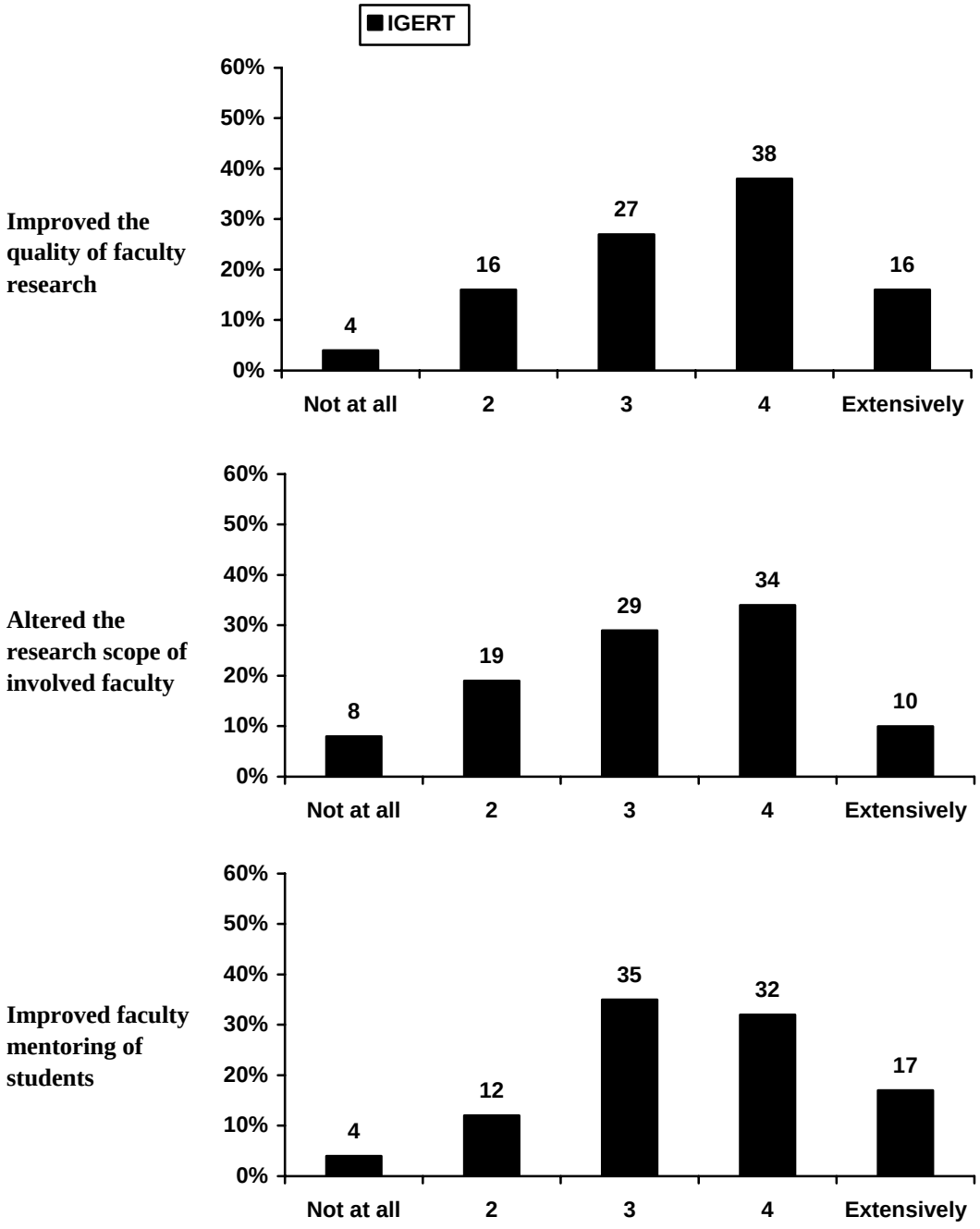
Many IGERT department chairs agree that participation in IGERT has impacted faculty behavior to some extent (Exhibit 4.8). Close to half of these chairs report that the IGERT grant has improved the quality of faculty research (54 percent), altered the research scope of involved faculty (44 percent), and improved faculty mentoring of students (49 percent).[49]

[49] Initial Impacts Survey of Department Chairs 2004. Based on those who selected response options "4" and "5" on a five-point scale where "1=not at all" and "5=extensively".

Exhibit 4.8

Percent of Department Chairs Reporting Impacts of the IGERT Grant on Their Departments' Faculty

"To what extent has the IGERT grant affected your department in the following ways?"



N= 77. (missing=8)

Note: Percentages do not sum to 100% due to rounding.

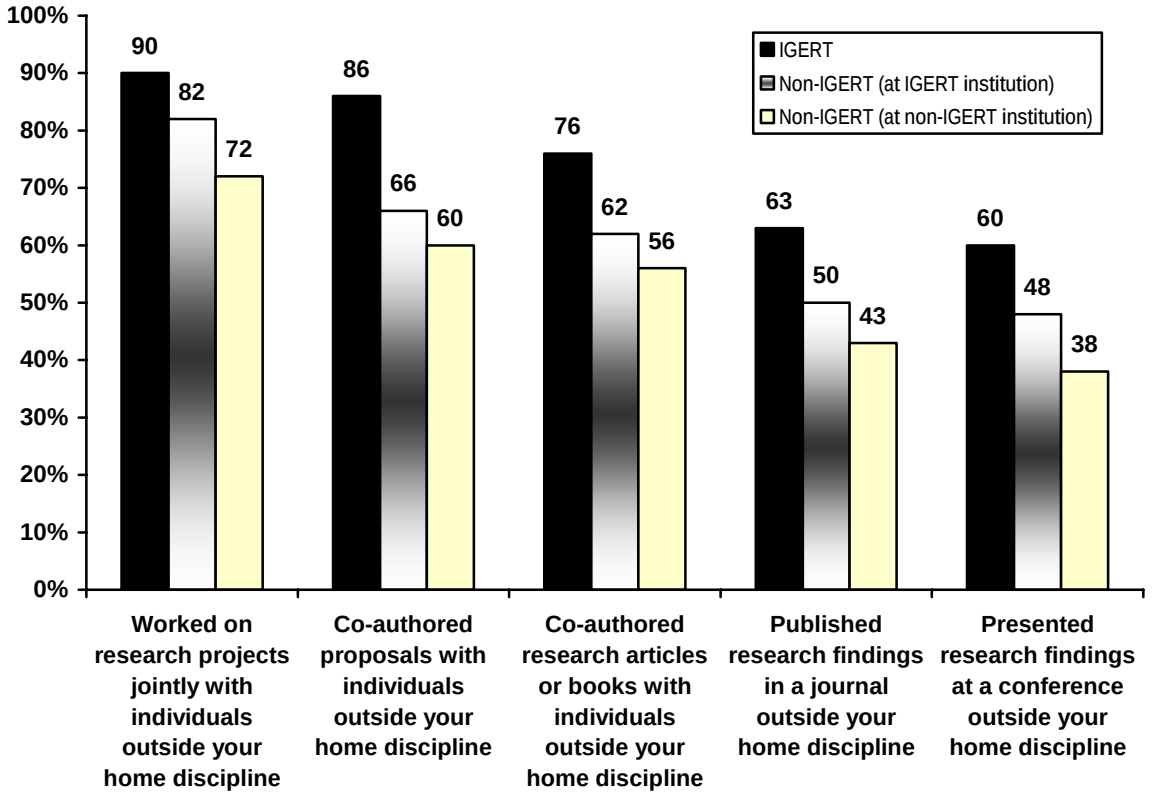
Source: Initial Impacts Survey of Department Chairs 2004.

Question: "To what extent has the IGERT grant affected your department in the following ways?"

When faculty engagement in interdisciplinary research activities is examined with the non-IGERT respondents split into those at institutions with and without IGERT projects, those at IGERT institutions consistently report greater engagement and productivity in interdisciplinary research than those at non-IGERT institutions (Exhibit 4.9). This suggests there may be something about the institutional environment of institutions with IGERT grants that has both attracted the IGERT project and encourages all faculty to participate in interdisciplinary work. It also suggests the possibility of added value for non-IGERT faculty at institutions with IGERT projects; these non-IGERT faculty perhaps benefit from the increased interest in working with colleagues from other disciplines reported by IGERT faculty.

Exhibit 4.9

Interdisciplinary Activities of Non-IGERT Faculty at Institutions With and Without IGERT Projects Compared to IGERT Faculty



IGERT N=346. Non-IGERT (with IGERT program) N=353. Non-IGERT (no IGERT program) N=196. Seven non-IGERT faculty members did not complete this question.

Source: Initial Impacts Survey of Faculty 2004.

Question: Have you engaged in any of the following research activities in the last two years?

Summary

IGERT has been successful in promoting a fertile environment for faculty to engage in interdisciplinary teaching and research. While interdisciplinary activities are common among all faculty surveyed, IGERT faculty and department chairs report an additional shift towards more interdisciplinary work as a result of IGERT participation. IGERT faculty members team-teach with colleagues outside their departments and mentor graduate students from other disciplines in greater frequencies than non-IGERT faculty members. A majority of IGERT faculty members report that participating in IGERT has enabled them to teach a greater variety of students and incorporate a broader range of topics in courses. With respect to interdisciplinary research, more IGERT faculty publish and present research in journals and conferences from outside their home disciplines, and are more likely to work on research projects and co-author publications with colleagues from other disciplines.

According to the IGERT faculty respondents, participating in the program has been a stimulating professional experience, one to which they are willing to devote substantial time with little direct compensation while generally maintaining other departmental responsibilities. Large majorities of the faculty members feel that IGERT enabled them to establish work with colleagues in other departments and exposed them to new ideas. About half of the faculty members reported learning new research techniques, exploring research that would not otherwise be funded, or being in a better position to win new grants as a result of IGERT. These outcomes suggest important benefits for faculty participating in IGERT that have the potential to increase support for interdisciplinary approaches to graduate education. The following chapter discusses the impacts of the IGERT program on award institutions and changes that institutions have made in response to the presence of IGERT projects.

Chapter 5: Impacts on Institutions

The IGERT program is intended to catalyze 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. We have discussed in previous chapters the ways in which IGERT has impacted participating students and faculty. In this chapter, we explore the ways in which IGERT projects have impacted the larger institutional context in which they operate, influencing institutional culture, policies, and structures. We address the following research questions:

- How have IGERT projects influenced institutional culture and support for interdisciplinary graduate education?
- How have IGERT projects impacted institutional policies and procedures?
- How have IGERT projects impacted institutional structures?
- What elements of IGERT projects have been institutionalized or adopted by other institutional programs?

Impacts on Institutional Culture

During interviews, university administrators identified several elements as key to establishing, maintaining, and expanding institutional support for interdisciplinary education, including support for interdisciplinary education in the institutional mission; leadership that values interdisciplinary education; and acceptance of interdisciplinary work by the institutional culture. While there is little evidence that IGERT projects have impacted institutional missions or leadership values, they have played a role in broadening acceptance of interdisciplinary work within their institutional cultures.

Administrators indicated that support for interdisciplinary graduate education at research universities is substantial and growing, and in general IGERT projects are situated at universities that support interdisciplinary graduate education in a variety of ways. Most IGERT department chairs report that their university supports inter/multidisciplinary graduate education (81 percent)[50] and that over the last five years their university's support for inter/multidisciplinary graduate education has increased (75 percent).

In general, university support for interdisciplinary *research* is stronger than that for interdisciplinary *education* at IGERT institutions. For example, twice as many IGERT department chairs report that their department supports cross-departmental faculty research collaboration (78 percent) compared to cross-departmental faculty team teaching (44 percent). IGERT faculty members also perceive much higher support for interdisciplinary research activities: 72 percent report their department chair values and rewards inter/multidisciplinary research and collaboration, while only 32 percent believe that interdisciplinary teaching is rewarded in the tenure/promotion process at their university.

[50] Reporting the percentage selecting '4' or '5' on a scale of 1 ("Not Supportive") to 5 ("Very Supportive") when asked "How would you describe your university's support for inter/multidisciplinary graduate education?

IGERT PIs were asked to describe concrete ways in which their central university administration supports inter/multidisciplinary graduate education. Exhibit 5.1 illustrates the various supports from the central administration as reported by PIs.

Exhibit 5.1

Percent of IGERT PIs Reporting Various Central University Administrative Support for Inter/Multidisciplinary Graduate Education

	Percent of PIs
Financial support for inter/multidisciplinary programs	81%
Provide policy support and encouragement for inter/multidisciplinary degree programs	79
Provide policy support and encouragement for cross-disciplinary courses	79
Allowing joint faculty appointments (faculty appointed in multiple departments)	77
Provide policy support and encouragement for cross-disciplinary team teaching	49
Allowing inter/multidisciplinary certificates	45

N=47 (missing =2).

Source: Initial Impacts Survey of PIs 2004.

Question: "In which of the following ways does your central university administration support inter/multidisciplinary graduate education?"

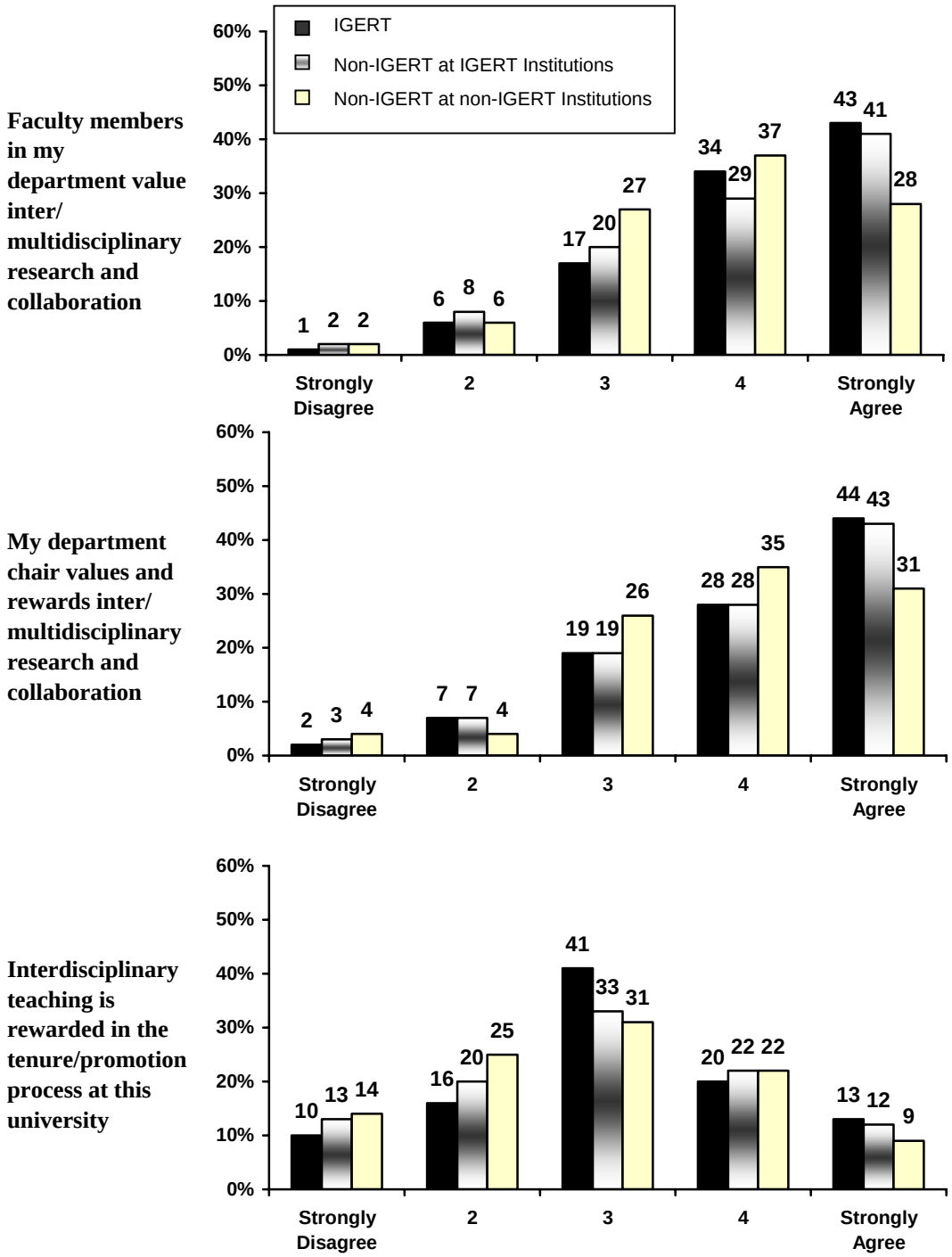
Faculty Perceptions of Institutional Support

Similar to department chairs and PIs, more faculty members report institutional support for interdisciplinary research than report that interdisciplinary teaching is rewarded in the tenure process at their institution. When the non-IGERT and IGERT groups are compared, there are not significant differences between the two in reporting on institutional support for interdisciplinary activities. However, when non-IGERT faculty are divided based on whether their home institution houses an IGERT grant, non-IGERT faculty members at IGERT institutions are more like IGERT faculty in their responses than those at non-IGERT institutions. This suggests that the culture of institutions that have been awarded IGERT grants is overall more supportive of interdisciplinary efforts than other institutions (Exhibit 5.2).

Exhibit 5.2 illustrates a correlation between the presence of an IGERT grant, and perceptions of faculty that interdisciplinary collaboration is valued at their institution. What we cannot determine is whether the presence of IGERT grants at an institution *causes* increased institutional support for interdisciplinary work, since data from these institutions was not collected prior to the IGERT awards. This question can be examined to some extent through the perceptions of IGERT participants.

Exhibit 5.2

Faculty Agreement with Statements about Support for Interdisciplinary Activities at Their Institution



IGERT N = 343. Non-IGERT/IGERT institution N = 357. Non-IGERT/non-IGERT institution N ranges between 198 and 199 due to missing responses. Percentages may not sum to 100 percent due to rounding.

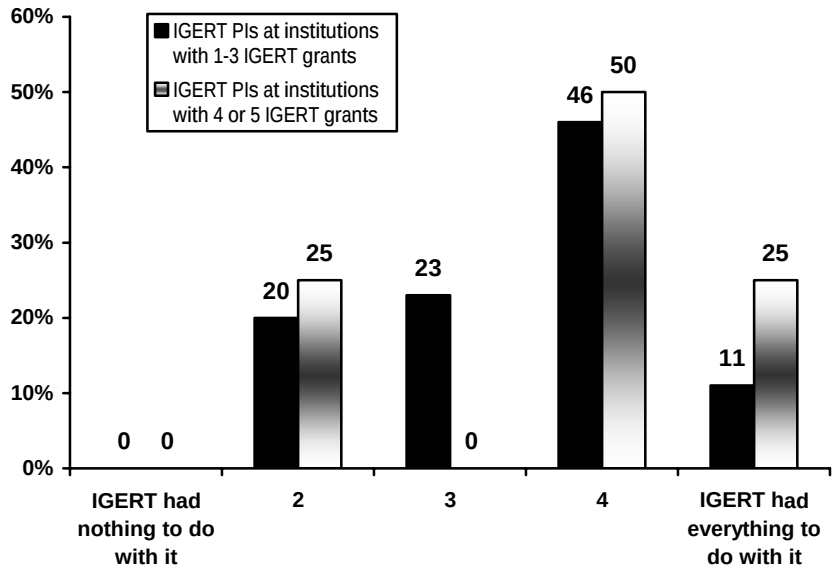
Source: *Initial Impacts Survey of Faculty 2004.*

Question: "To what extent do you agree or disagree with the following statements about inter/multidisciplinary research and teaching at your university?"

IGERT participants do believe that their IGERT grants have had an impact on institutional support of interdisciplinary graduate education. Of the 83 percent of PIs who report that their university's support for inter/multidisciplinary graduate education has increased since they won the IGERT grant, three fifths attribute this change in large part to the presence of the IGERT grant(s) on campus (58 percent). PIs at institutions with four or more IGERT grants are also more likely than their counterparts at institutions with three or fewer grants to attribute increased institutional support to the IGERT grant, suggesting a cumulative effect of multiple IGERT grants (Exhibit 5.3).

Exhibit 5.3

To What Extent are Recent Increases in Your University's Support for Inter/Multidisciplinary Graduate Education the Result of the IGERT Grant? (Percent of PIs)



N (1-3 IGERTS)=35. N (4-5 IGERTS)=4.

Note: Reported only for PIs who indicated that their university' support for inter/multidisciplinary graduate education has increased since they won the IGERT grant.

Source: Initial Impacts of Survey of IGERT PIs 2004.

Question: "To what extent do you attribute this change [increase in support] to the presence of the IGERT grant(s) on campus."

Given that IGERT PIs perceive that IGERT grants are effecting institutional change, how might IGERT projects be increasing institutional support for interdisciplinary graduate education? The data suggest several ways, including:

- broadening campus awareness of interdisciplinary graduate education through increased involvement of faculty members in IGERT activities, and
- broadening the research foci of participating faculty and departments to include interdisciplinary topics.

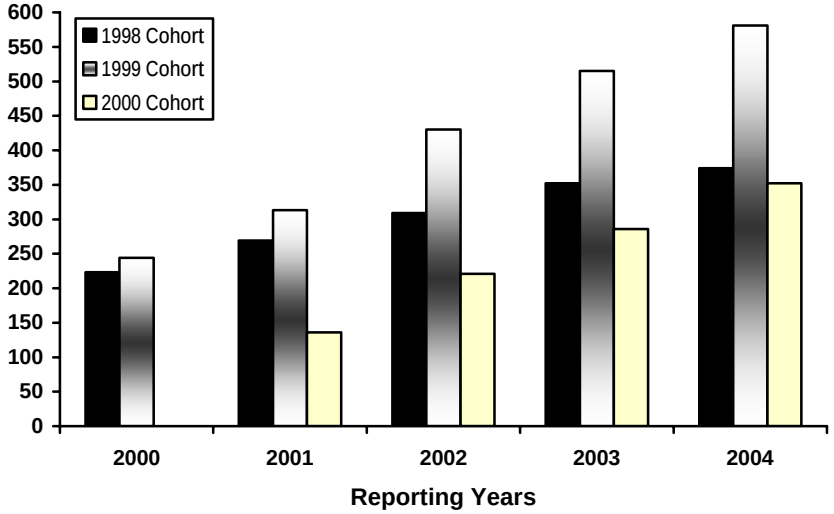
Broadening campus awareness of interdisciplinary graduate education

IGERT projects involve faculty members from between 1 and 24 departments / academic units, with an average of 7 to 8 departments involved in any one IGERT project. It is rare for more than half of a department's faculty members to be involved with the IGERT grant; department chairs report it more likely that one quarter or less (68 percent) or between 26 and 50 percent (23 percent) of their department's faculty members are involved with the IGERT grant.

Thus IGERT faculty members tend to be situated within departments containing non-IGERT faculty members. One sign of IGERT projects' increasing presence on campuses is that 89 percent of project PIs report an increase in participating faculty members since funding began. Exhibit 5.4 illustrates the growth in numbers of IGERT faculty members involved in projects in the first three cohorts. As more faculty members become involved with each IGERT project, word of the IGERT model of education likely spreads throughout the campus. This possibility is supported by data from non-IGERT faculty members: non-IGERT faculty members at institutions with IGERT grants were more likely to know about the IGERT program (62 percent) than non-IGERT faculty members at institutions without IGERT grants (54 percent) (p=.0587). Non-IGERT faculty at institutions with an IGERT grant who have heard of IGERT reported most commonly hearing about IGERT from NSF grant announcements (73 percent); colleagues at their own institution (72 percent); or information about the IGERT grant at their university (45 percent).

Exhibit 5.4

Number of Faculty Members Involved in IGERT Projects Over Time, by Cohort



Note: Reporting the number of faculty members listed in the IGERT monitoring system as serving as Co-PIs or Advisors to trainees. Does not include PIs. Number of projects in each cohort: 1998 (17); 1999 (21); 2000 (19).

Source: IGERT Distance Monitoring Web System, reporting years 2000, 2001, 2002, 2003, and 2004.

Broadening faculty research foci

IGERT projects have also increased support for interdisciplinary work by broadening the research foci of involved faculty members, which has an impact on participating departments. Department chairs report, for example, that the IGERT grant has expanded the department's research focus (60

percent). And as reported in Chapter 4, IGERT faculty likewise report that participating in IGERT has made them more likely to conduct research with colleagues in disciplines outside their own. Thus as IGERT projects involve more faculty, and those faculty who become involved experience broadened research activities and collaborative possibilities, IGERT grants have the potential to impact the culture of support for interdisciplinary research and education on their campuses.

Impact on Institutional Policies and Procedures

Although institutional cultures are becoming more accepting of interdisciplinary work, institutional policies may be slow to change. One IGERT Vice Provost for Graduate Studies & Dean of the Graduate School commented that existing policies that get in the way of interdisciplinarity are not usually mechanisms of active resistance but just inertia. Institutional policies impacting the ability of IGERT projects to implement interdisciplinary graduate education center around tenure promotion, and balancing disciplinary versus interdisciplinary educational activities.

Impact of IGERT on Tenure Review Policies

Most administrators we interviewed cited tenure review policies as a common barrier to support for interdisciplinary research and graduate education. Administrators report that conversations about how to incorporate interdisciplinary activities into the tenure process have been happening for decades. A few administrators are starting to see some changes, though they acknowledge that institutional change takes a long time. Some institutions have begun to require input from interdisciplinary institutes and centers, if applicable, when reviewing a faculty member in their home department. Issues still to be worked out include how to systematically incorporate this feedback, and exactly how it should count; since the very nature of interdisciplinary work is that it is unique and varies greatly across topics and projects. Another issue is how to weigh publications and research grants: traditional requirements for up-and-coming faculty members to have published in peer-reviewed journals (ideally as first author) and to have acquired funding to do discipline-based research have deep historical roots.

A few administrators mentioned conversations at their institutions about having tenure review teams that are themselves multidisciplinary, rather than a single disciplinary review team getting input from an interdisciplinary source. While this idea is being considered, it poses a fundamental question on how to establish criterion for evaluating work that has no established standards while maintaining the highest expectation of quality. As one IGERT administrator explains,

> It works like this: many traditional scientific disciplines, when looking at promotion/tenure, are looking for evidence that [faculty members] have initiated creative work. When [work has a] single author, it's easy to see. When there are ten authors [on a paper], on a subject that crosses disciplinary boundaries, it's harder to see.

Perhaps as a result of these challenges, as was illustrated in Exhibit 5.1, only a third of IGERT and non-IGERT faculty believe that interdisciplinary teaching is rewarded in the tenure/promotion process at their university. It does not appear that IGERT grants have had much impact on these policies: 81 percent of IGERT PIs said the IGERT grant did *not* result in changes in criteria for faculty promotion, tenure, or merit awards at their university or other universities participating in their project.

Tenure status of Faculty Engaging in Interdisciplinary Work

A related issue raised by many administrators concerns the interplay between the protection offered by tenure to faculty members interested in engaging in interdisciplinary work, and the likelihood that junior (untenured) faculty are more often interested in conducting interdisciplinary work than senior (tenured) faculty. Newer faculty members have often had exposure to interdisciplinary work in their doctoral programs. However, it is more established faculty members who already have tenure and therefore the security to work across disciplinary boundaries. According to administrators, conversations about how to protect younger faculty and leverage their interdisciplinary involvement are common.

While administrators reported that tenured faculty have more freedom to engage in interdisciplinary work, the proportion of IGERT faculty who are tenured is not significantly different that of our non-IGERT sample (78 versus 73 percent).[51] This contradicts the expectation that we would see fewer non-tenured faculty members in the IGERT sample than in the non-IGERT sample, suggesting that non-tenured faculty members feel secure in participating in the IGERT program.

Tenured faculty in both samples are more likely to have engaged in various interdisciplinary research activities in the last two years (Exhibit 5.5). However, *non-tenured IGERT faculty* are more likely to engage in these activities than *tenured non-IGERT faculty*; also suggesting that IGERT projects may provide support and encouragement to untenured faculty desiring to engage in these activities. Overall, the responses shown in Exhibit 5.5 indicate that interdisciplinary research activities are common among all faculty respondents.

[51] Reporting only tenured or tenure-track faculty – non-tenure-track faculty comprise 4 percent of the IGERT sample, and 6 percent of the Comparison sample, and were excluded for this analysis.

Exhibit 5.5

Tenured vs. Non-Tenured[52] Faculty Engagement in Interdisciplinary Research Activities

	IGERT		Non-IGERT	
	Tenured (N=255)	Non-tenured (N=87)	Tenured (N=383)	Non-tenured (N=173)
Worked on research projects jointly with individuals outside your home discipline	90%	90%	80%	75%
Co-authored proposals with individuals outside your home discipline	87	83	67	57
Co-authored research articles or books with individuals outside your home discipline	79	67	64	50
Published research findings in a journal outside your home discipline	65	56	53	35
Presented research findings at a conference outside your home discipline	64	48	44	45
Mentored any graduate student(s) outside your home discipline	67	66	49	44
Been awarded new research grants, either singly or as part of a team	81	76	66	65

Source: Initial Impacts Survey of Faculty 2004.

Question: "Have you engaged in any of the following research activities in the last two years?"

Policies Governing Interdisciplinary Teaching

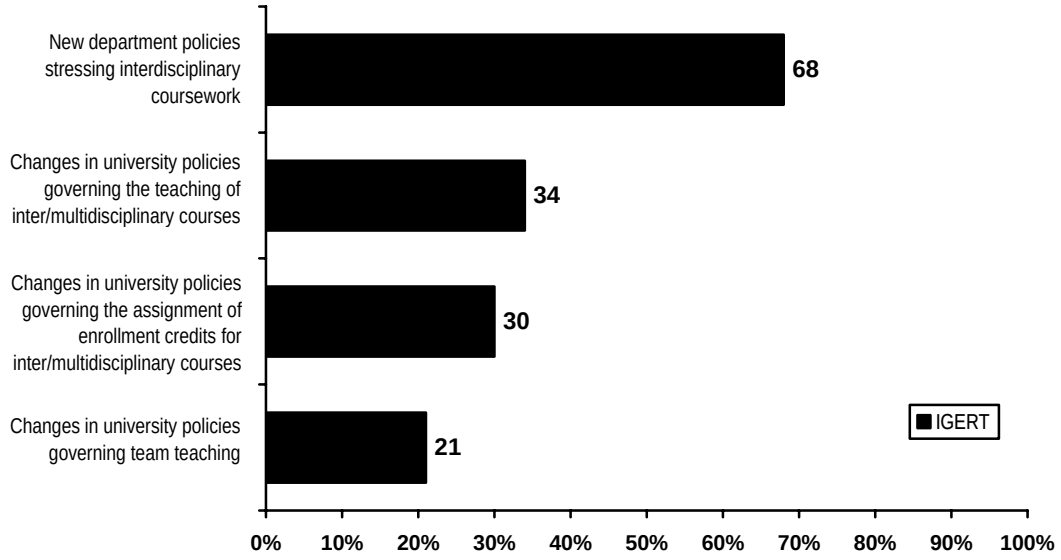
Many administrators we interviewed commented that an institution's support for, or barriers against, interdisciplinary courses and team-teaching impacts how willing faculty are to engage in these activities. Forty-nine percent of PIs report that their central university administration provides policy support for cross-disciplinary team-teaching. While teaching policies are not as high a priority as research policies at doctoral granting institutions, IGERT institutions are nonetheless more supportive towards interdisciplinary teaching. Sixty-three percent of IGERT department chairs compared to 39 percent of non-IGERT department chairs report that teaching inter/multidisciplinary courses is both supported by department policy and informally encouraged. Seventy-eight percent of PIs report at least some change in university policies due to IGERT, including new departmental policies stressing interdisciplinary coursework, changes in university policies governing team teaching, assignment of enrollment credit for inter/multidisciplinary courses, the teaching of inter/multidisciplinary courses, and changes in criteria for faculty promotion, tenure, or merit awards. These findings suggest that IGERT is contributing to changes in institutional policies supporting interdisciplinary graduate education.

[52] Non-tenured is defined as either non-tenure-track or tenure-track, not tenured.

Exhibit 5.6

Percent of IGERT PIs Reporting Changes in University Policies Resulting from the IGERT Grant

"Our IGERT grant has resulted in the following changes:"



N=47 (missing=2).

Source: Initial Impacts Survey of PIs 2004.

Question: "Has the IGERT grant resulted in any of the following changes at your university (or other universities participating in your project)?"

Impact on Institutional Structures

As institutional cultures and policies become more supportive for interdisciplinary graduate education, institutional structures such as faculty appointments, courses, and degree programs are altered. IGERT projects have been responsible for some of these changes. In the words of an Associate Provost, "You can look at IGERT as a catalyst. It provides a scope of possibility, and funding. IGERT provides the opportunity to explore ways to break down barriers."

Joint Faculty Appointments

Nearly all the administrators we interviewed discussed joint appointments – that is, faculty members with appointments in multiple departments – as a way for faculty members to begin to find homes in departments beyond their primary department and have access to resources and information of multiple departments, thereby mitigating departmental barriers. Joint faculty appointments were expressed as a popular way to allow faculty to bridge disciplines while maintaining overall departmental organization. This strategy is clearly common at IGERT institutions, as 77 percent of PIs report that their central university administration allows joint faculty appointments. While the degree to which faculty members obtain joint appointments varies, one IGERT Dean of the Graduate

Division described his/her institution's organization as "very fluid," with a third of their faculty members having joint appointments in two or more departments.

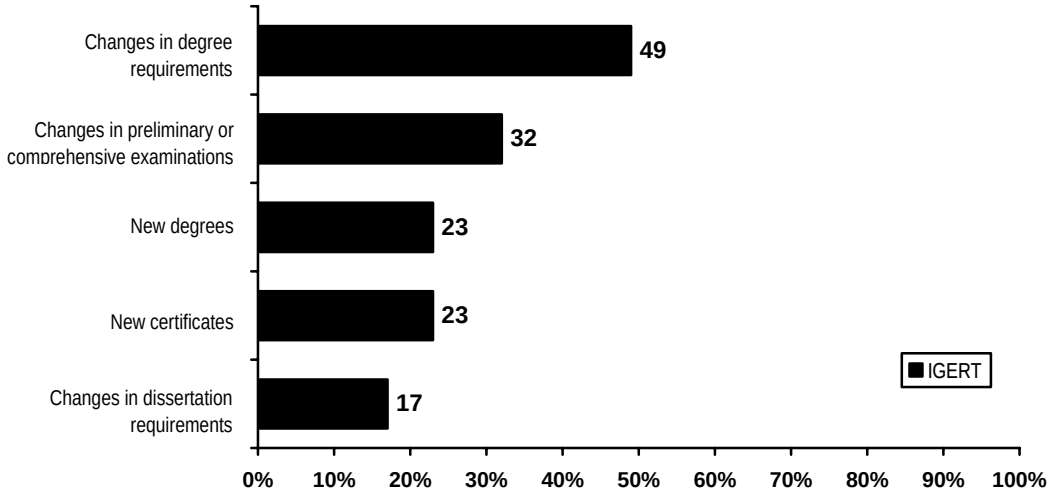
New Interdisciplinary Courses/Degrees/Certificates

The administrators we spoke with indicated that support for new interdisciplinary courses, degrees and certificates are measures of an institutional culture open to advancing interdisciplinary graduate education. The IGERT institutions are in general supportive of such efforts: 79 percent of PIs report that their central university administration provides policy support and encouragement for inter/multidisciplinary degree programs and/or for cross-disciplinary courses. IGERT PIs also report changes to doctoral educational structures as a result of IGERT projects, most commonly with respect to degree requirements and exams (Exhibit 5.7). New degrees or certificates are reported by approximately one-forth of PIs, a substantial number given the effort and time typically required to develop new degree programs at universities.

Exhibit 5.7

Percent of IGERT PIs Reporting Changes in Educational Structures Resulting from the IGERT Grant

"Our IGERT grant has resulted in the following changes:"



N=47 (missing=2).

Source: *Initial Impacts Survey of PIs 2004.*

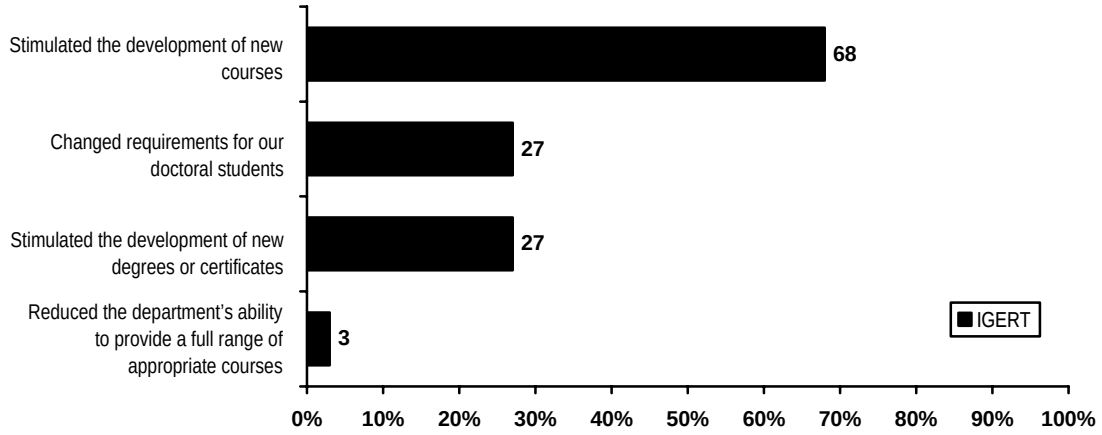
Question: "Has the IGERT grant resulted in any of the following changes at your university (or other universities participating in your project)?"

According to department chairs, most IGERT projects have led to the creation of new courses, and a sizable minority of projects have stimulated the development of new degree programs or altered degree requirements (Exhibit 5.8). The level of recognition that department chairs afford IGERT, by reporting on project impacts at large, can be taken as one sign of the IGERT grants' profile within their universities, given that department chairs do not always know what various faculty members are engaged in.

Exhibit 5.8

Percent of IGERT Department Chairs Reporting Changes in Educational Structures Resulting from the IGERT Grant

"Has the IGERT grant affected your department in the following ways?"



N=77.

Note: Reporting the percentage who selected 4 or 5 on a 5-point scale from 1 ("Not at all") to 5 ("Extensively").

Source: Initial Impacts Survey of Department Chairs 2004.

Question: "To what extent has the IGERT grant affected your department in the following ways?"

Interdisciplinary Centers and Institutes

Research institutions have housed interdisciplinary centers and institutes for several decades. However, most administrators agree that in the last five years the prestige, accessibility and visibility of many of these centers and institutes have grown. These centers and institutes provide an intellectual and physical space for collaboration, and are often highlighted when administrators discuss the interdisciplinary landscape at their institution.

Students are becoming increasingly involved in interdisciplinary institutes. One Graduate School of Arts and Sciences Dean at a non-IGERT institution described a funding program through which graduate students nearing completion of their degree can apply to an interdisciplinary institution, at which they then work while finishing their dissertation. Students present their work every other week to each other, fostering interdisciplinary communication along the lines that IGERT supports. Another administrator explained that in order to create competition and increase prestige, there is competition for graduate students to be accepted into an interdisciplinary institute where they either receive funding from the administration or resources for their research. Along similar lines, one administrator explained that at his/her institution faculty are only allowed to form an Institute at all if it spans across multiple departments, which sends a strong message about the value of interdisciplinarity. The merging of more than one discipline is a major tenet of IGERT, so it is no surprise that several IGERT administrators describe the IGERT project on their campus as having spawned and/or facilitated the expansion of institute(s) on campus.

Leveraging Funds

Several administrators we spoke to mentioned that IGERT was useful in leveraging funds. IGERT PIs and department chairs echo this observation: 89 percent of PIs report that the presence of the IGERT grant has enabled them to leverage additional university resources and 52 percent of IGERT department chairs report that IGERT has increased the department's ability to leverage funds.

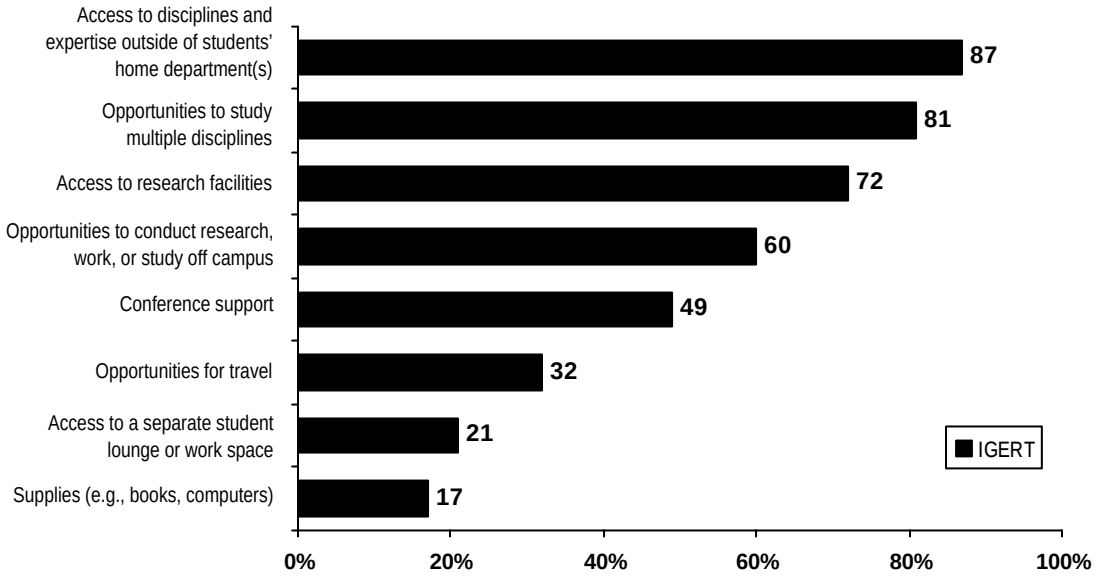
Institutionalization and Spread of IGERT Elements

Sustainability

PIs are confident that they will be able to maintain some student benefits associated with IGERT beyond the funding period, with only four percent reporting that no benefits will be maintained. The most likely benefits to be maintained include those associated with the interdisciplinary nature of the IGERT educational experience – access to disciplines outside students' home departments, and opportunities to study multiple disciplines – suggesting that the interdisciplinary models of education developed by IGERT grants are perceived as valuable (Exhibit 5.9).

Exhibit 5.9

Percent of PIs Reporting IGERT Benefits They Expect to Maintain (Post Funding)



N=47, (missing=2).

Source: *Initial Impacts Survey of PIs 2004.*

Question: Which of the following student benefits often associated with IGERT do you expect to be able to maintain?

PIs are less confident that they will be able to maintain IGERT levels of unrestricted student support, that is, funding that is not tied to specific responsibilities for teaching or research, and which is not linked to a single faculty member or department. Some PIs report that they will either fully (11 percent) or partially (48 percent) maintain such funding; the remaining 41 percent do not see this happening. When asked how they planned to maintain IGERT levels of student support, PIs most frequently pointed to faculty grants or university funding (70 and 63 percent, respectively). They were less likely to suggest that they would rely on departmental funding (44 percent), non-NSF federal funding (44 percent), or other NSF funding (37 percent).

Adoption of IGERT Features by Others

Fifty-nine percent of PIs report that other departments or programs at their university have adopted IGERT program elements. Several administrators pointed to the spread of IGERT features as the core impact of the IGERT grant(s) at their institution. Sometimes IGERT features spread across from IGERT departments to non-IGERT departments, and sometimes they spread more systematically across the whole university. Two IGERT administrators highlight various ways IGERT elements spread.

> I think [IGERT has spread to other departments] simply because those departments that do not have IGERT's look upon the departments that do have them with a considerable amount of envy. [It is] stimulating to see that interdisciplinary activities are not just productive for one's research or for training better students but can [also] bring money. (IGERT Dean of the Graduate Division)

> Our IGERT grant happened to involve the center for computational biology, chemistry, microbiology, etc, and it just works wonderfully. [Students] can run through three or four labs, meet three or four possible mentors, and when they get done that first year they have a good idea of what lab they want to take, where they want to be. That has led us to a campus [IGERT-like] program in molecular biosciences, supported by the campus that is multi-departmental, for which students come in and have a year to work through honing their interest, then settle down in one department and earn their degree. (IGERT Dean of the College of Graduate Studies).

Summary

Findings from the surveys and interviews suggest that IGERT projects are helping advance interdisciplinary graduate education in their institutions. Project PIs report that their projects have led to policy changes for interdisciplinary coursework and teaching, revised degree requirements, and created new degrees and certificates, as well as increased university support for interdisciplinary education in general. Participating department chairs point to IGERT grants as stimulating the development of new courses, and to a lesser extent, new degrees and requirements for doctoral students. Additionally, faculty members and department chairs perceive stronger departmental and institutional support for interdisciplinary research and education at IGERT institutions than non-IGERT institutions, though support for interdisciplinary education overall is modest compared with interdisciplinary research.

These reported institutional impacts vary across projects and may appear to be small within the scope of universities, but they are an indication that IGERT is catalyzing changes in graduate education via a funding mechanism that primarily supports graduate students. PIs are confident that they will be

able to maintain some project benefits beyond the funding period, especially access to disciplines and expertise outside of students' home departments, and opportunities to study multiple disciplines. Many PIs and administrators report that other departments or programs at their home institutions have already adopted IGERT program elements. In the next chapter we will examine the success of the IGERT program in increasing participation of individuals from diverse backgrounds.

Chapter 6: Impacts on Recruitment

The IGERT program is intended to facilitate "diversity in student participation and preparation," and contribute to the "development of a diverse, globally-engaged, science and engineering workforce." Diversity is a multi-faceted concept, and includes (but is not limited to) diversity in academic ability, professional preparation, career goals, disciplinary or interdisciplinary background, ethnicity, race, or gender. By design, only United States citizens or permanent residents may receive IGERT funding, as part of NSF's efforts to attract more American students to science, technology, engineering, and mathematics (STEM) Ph.D. programs. Recruiting and enrolling students from diverse backgrounds and groups traditionally underrepresented in STEM fields has also been an emphasized priority of the IGERT program since its inception, in response to the underrepresentation of such individuals in American STEM Ph.D. programs. In support of the NSF's commitment to these goals, in 2002 NSF funded the IGERT National Recruitment Office (INRP), a stand-alone program dedicated to helping IGERT projects enhance recruitment of these targeted groups. In evaluating the IGERT program's success in recruiting diverse students to participate, all of these facets of diversity are examined.

As of spring 2005, IGERT projects have successfully supported over 2900 American citizens, and IGERT Principal Investigators (PIs) and faculty report that IGERT students are talented and diverse IGERT faculty assert that IGERT students bring new ideas and energy to their university. The IGERT program has been successful in maintaining diverse recruitment of underrepresented groups on par with national averages of the disciplinary fields represented in IGERT. In this chapter we explore the IGERT program's impact on the involved doctoral programs' capacity to recruit a diverse pool of applicants, and examine the characteristics of enrolled IGERT trainees as compared to non-IGERT students. This chapter addresses the following research questions:

- What is the added recruitment value of the IGERT project?
- What are the characteristics of students being recruited into IGERT programs, and how do they differ from traditional graduate students?

Increasing Access in Higher Education

Increasing Participation of United States Citizens

United States citizens received 62 percent of all science and engineering Ph.D. degrees awarded in 2003, a figure that has been slightly declining over the last ten years.[53] To encourage enrollment in STEM doctoral education by American students, the NSF requires that all IGERT trainees must be United States citizens or permanent residents. Thus the IGERT program has the long-term potential to influence the proportion of Ph.D. degrees being earned by United States citizens. Given that many IGERT students have yet to graduate, it is relatively early to determine how much impact the IGERT program will have on the number of United States citizens earning degrees. Approximately 20 percent of IGERT students surveyed indicated that they might not have attended graduate school had the IGERT graduate program not been in existence. It is anticipated that by 2007-08 IGERT

[53] 2004 Science and Engineering Doctorate Awards. Division of Science Resources Statistics, National Science Foundation.

programs will be graduating approximately 500 individuals per year[54], meaning that if 20 percent continue to be individuals who otherwise might not have pursued a doctoral degree, IGERT could be responsible for about 100 new American STEM graduates per year.[55]

Increasing Participation of Underrepresented Groups (Women and Minorities)

A further goal of the IGERT program is to increase participation in STEM doctoral education by groups underrepresented in STEM fields, including women and minorities. In spite of the challenges associated with developing new doctoral degree programs, the IGERT program has been successful in maintaining recruitment of women and minority students on par with national averages of the disciplinary fields represented in IGERT. Nationwide, women received 38 percent of all science and engineering Ph.D. degrees awarded in 2003, while underrepresented[56] minorities received 12 percent.[57] Some IGERT projects have effectively recruited higher numbers of students from these groups, while others have not. Overall, of the active trainees, 35 percent are women and 9 percent come from minority groups underrepresented in STEM disciplines: Black, Native American, or Hispanic. An analysis of data from the web monitoring survey reveals that in 2003, 32 percent of projects with trainees report having no students from underrepresented minority groups, 39 percent report between one and 13 percent, and 30 percent report greater than 13 percent underrepresented minorities.[58] One-third (36 percent) of the IGERT department chairs[59] report that the IGERT has enabled them to attract more underrepresented minority students than before.[60]

PIs responding to the 2003 Monitoring Web Survey identified multiple approaches to recruiting students from underrepresented groups. Almost all projects use faculty contacts, non-electronic media, competitive stipends, and visits to campus as tools in recruiting students. The most successful recruitment of students to IGERT projects comes through personal connections faculty or other students have with prospective applicants. Across the five cohorts funded through 2002, 80 percent of the PIs reported ensuring that entry requirements do not unnecessarily exclude prospective students. Other strategies include recruiting through minority science organizations (73 percent), offering research experiences for undergraduates (68 percent), and making informational visits to minority serving colleges (47 percent).

During site visit interviews, some PIs pointed out that statistics on the involvement of underrepresented minorities in IGERT may underestimate actual involvement, because students from underrepresented minority groups participating in IGERT projects do not always receive IGERT funding due to the availability of other sources of funding specifically earmarked for

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54 IGERT Distance Monitoring Web System 2004.

55 Projections based on data from IGERT Distance Monitoring Web System 2004.

56 American Indian/Alaskan Native, Black, Hispanic, Puerto Rican, Mexican American, and Other Hispanic.

57 2004 Science and Engineering Doctorate Awards. Division of Science Resources Statistics, National Science Foundation.

58 Percents do not equal 100 due to rounding.

59 Initial Impacts Survey of Department Chairs 2004. Question: "Has the presence of the IGERT grant had an impact on your departmental admissions in any of the following ways?"

60 All data from "*IGERT Annual Report.*" Prepared by Abt Associates Inc. for the National Science Foundation. Cambridge MA: Abt Associates, Spring 2005.

underrepresented minorities. In other words, students with minority scholarships or fellowships do not also need the IGERT support, but may still participate in the IGERT program.

Increasing Interest in Doctoral Education Among Undergraduates

IGERT projects have had some perceived impact on stimulating interest in STEM graduate education among undergraduates, with 49 percent of PIs reporting that their IGERT grant has led to increased interest among undergraduates in pursuing STEM graduate degrees.[61] In an attempt to diversify the student body and to increase the number of undergraduates interested in science and engineering programs who enter the graduate education pipeline, some projects have also begun long-term collaborations with minority serving colleges (47 percent) and offer research experiences for undergraduates at IGERT institutions (68 percent).[62]

Student Characteristics

Not surprisingly given the increased funding available for student support, IGERT grants have enabled participating departments to recruit **more** students to their programs. Nearly all PIs (94 percent), and 72 percent of IGERT department chairs, report they can recruit more students because of IGERT. This is confirmed by findings that more IGERT department chairs than non-IGERT department chairs report an increase in the number of applications to their departmental doctoral programs in the last five years (75 percent and 69 percent, respectively). Department chairs also report that IGERT has attracted students with more diverse career goals (59 percent) and disciplinary backgrounds (67 percent). In addition, IGERT department chairs report that more students inquire into their programs because of IGERT (64 percent).

IGERT grants have also enabled participating programs to recruit more highly qualified students, as reported by 85 percent of PIs, and 72 percent of IGERT department chairs. Similarly, three quarters of the IGERT faculty believe that the students in the IGERT program are better qualified than the usual department students in terms of their academic and research potential. When asked to compare their IGERT students' academic and research potential with graduate students they normally see, IGERT faculty rated their IGERT students as "Far superior" (16 percent), "Somewhat better" (59 percent), "About the same" (21 percent), or "Somewhat less promising" (4 percent).

Non-IGERT students reported significantly higher average GRE scores than the IGERT students, as shown in Exhibit 6.1. Given the faculty perception that IGERT students are better qualified, it is possible that IGERT projects attract a different type of student, whose academic talent is not reflected in measures like the GRE score.

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[61] Initial Impacts Survey of PIs 2004. Question: "To what extent do you agree with the following statements about the impact of the IGERT grant at your institution? The IGERT grant has led to increased interest among undergraduates in pursuing STEM graduate degrees."

[62] *IGERT Annual Report* 2005.

Exhibit 6.1

GRE Scores for IGERT Students and U.S. Citizen Non-IGERT Students

		N	Mean	Min	Max
Verbal	IGERT	227	576 **	320	790
	Non-IGERT	178	619	330	800
Quantitative	IGERT	227	713 **	340	800
	Non-IGERT	182	738	430	800
Analytic	IGERT	226	692 ***	280	800
	Non-IGERT	179	737	420	800

Significance denoted as: *(p<.01) **(p<.001) ***(p<.0001)

Note: Foreign non-IGERT students were excluded from this analysis.

Source: Initial Impacts Survey of Students 2004.

Question: What were your GRE scores?

We also examined differences in professional productivity, such as publications and presentations. There are no significant differences between IGERT and non-IGERT students (Exhibit 6.2). Half of both groups have authored or co-authored a journal article in the last two years.

Exhibit 6.2

Professional Productivity of IGERT and Non-IGERT Students

	Percent reporting accomplishments in last two years		Of those, average number of each	
	IGERT (N=306)	Non-IGERT (N=566)	IGERT	Non-IGERT
Journal articles in refereed journals	55%	53%	2	2
All other publications	41	38	3	3
Book chapters	13	10	1	1
Patent applications	8	7	1	1
Approved patents	3	1	1	1
Books	2	1	1	1

Source: Initial Impacts Survey of Students 2004.

Question: "Please provide counts of any professional publications you have authored, or patents you have applied for or won, during the past two years. Count all publications and/or patents that include your name as an author."

While equal numbers of IGERT and domestic non-IGERT students have attended conferences at their home institutions or within the United States (Exhibit 6.3), IGERT students are significantly more likely to have presented a poster at these events (p<.01). IGERT students are also more likely than domestic non-IGERT students to have attended a conference outside the United States (p<.05).

Exhibit 6.3

Conference Attendance of IGERT and U.S. Citizen Non-IGERT Students

	Number responding		Attended Conference		Presented a Poster		Presented a Paper	
	IGERT	Non-IGERT (U.S.)	IGERT	Non-IGERT (U.S.)	IGERT	Non-IGERT (U.S.)	IGERT	Non-IGERT (U.S.)
At home institution	299	336	67%	62%	41%**	29%	20%*	15%
Within the US (outside the home institution)	306	341	85	79	55**	44	47	41
Outside the US	286	325	37*	28	17	13	18	14

Significance denoted as: * (p<. 05) **(p<. 01)

Note: Foreign non-IGERT students were excluded from this analysis.

Source: Initial Impacts Survey of Students 2004.

Question: "Please provide the following information for conferences you have attended inside and outside your home institution: (a) Counts of conferences you have attended; (b) Counts of conference poster sessions in which you have participated; (c) Counts of conference presentations you have made."

Expanding Interdisciplinary Graduate Education Opportunities

As a result of the IGERT program, new interdisciplinary graduate programs or experiences are available to students who otherwise might not have such opportunities. IGERT projects have expanded educational opportunities and in doing so, have the potential to attract new students to graduate education. Both IGERT and non-IGERT graduate students report having applied to a mixture of single and inter/multidisciplinary programs, indicating an awareness of and interest in inter/multidisciplinary education (Exhibit 6.4). Close to half (46 percent) of the current IGERT students report having applied to other inter/multidisciplinary programs; only one third (34 percent) applied only to other single disciplinary programs. Conversely, only a third of non-IGERT students applied to an inter/multidisciplinary program, while the majority applied only to single disciplinary programs. These responses suggest a greater tendency among IGERT students to have sought out interdisciplinary experiences when applying to graduate school.

Exhibit 6.4

Programs to which IGERT and Non-IGERT Students also Applied when Applying to Their Current Program

	IGERT (N=306)	Non-IGERT U.S. Citizens (N=343)	Non-IGERT Foreign (N=223)
I applied to (other) single discipline programs	34%	50%	25%
I applied to a mix of other single discipline and inter/multidisciplinary programs	28	19	20
I applied only to this program	21	20	43
I applied to (other) inter/multidisciplinary programs	18	11	13
Total who applied to at least one inter/multidisciplinary program (including IGERT)	100	30	33
Total who applied to at least one other inter/multidisciplinary program (excluding IGERT)	46	- -	- -

Note: The Non-IGERT students have been split out into U.S. Citizens, and non-U.S. Citizens/Foreign, due to the high proportion of foreign students who only applied to one program.

Source: Initial Impacts Survey of Students 2004.

Question: "When you applied to this graduate program, to what other types of graduate programs did you apply?"

Summary

IGERT projects have had a clear impact on the ability of participating programs to recruit, in the perception of faculty, **more** and **better academically qualified** individuals, and have the potential to increase the number of United States citizens currently enrolled in STEM doctoral programs. IGERT PIs and faculty members report successfully recruiting high quality students, including those students for whom the availability of an IGERT program was a factor in choosing to attend graduate school. IGERT projects provide an interdisciplinary alternative to what might otherwise be available to students, and IGERT students are more likely to pursue interdisciplinary education than their non-IGERT counterparts. The IGERT program has recruited minorities and women in science and engineering programs at rates equal to national averages. While IGERT projects have shown success in their recruitment efforts, the goal of the IGERT program is to be a leader in increasing diversity, and this challenge will continue to be a major focus of the program. The continued recruitment efforts of individual IGERT projects may in the future further increase the diversity of students enrolling in IGERT projects in these areas. The next chapter summarizes evaluation findings and suggests areas for future study.

Chapter 7: Conclusions and Directions for Future Research

This study examined the impacts of the IGERT program in achieving the following program goals:

- **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.

The success of the IGERT program in achieving these goals was examined through its impacts on students, faculty, institutions, and recruitment. Overall the IGERT program has had the most observable impact in the goal of developing interdisciplinary graduate education experiences for participating students. This may be because the bulk of program funding at each project site goes directly to support individual students and the costs associated with their education, rather than to faculty members or participating departments.

Educating United States Ph.D. Scientists and Engineers

The IGERT program has successfully created new, innovative, integrative interdisciplinary educational experiences for doctoral students across the nation. IGERT students report significantly broader and more interdisciplinary educational experiences than non-IGERT students. IGERT projects have organized around interdisciplinary themes, resulting in opportunities for IGERT students to work with students and faculty in other disciplines, take courses in other departments, conduct laboratory research in a variety of disciplinary settings, and work in interdisciplinary teams. IGERT students gain breadth of skills and knowledge, often taking "bridge" courses to bring them up to speed in other disciplines or conducting a series of laboratory rotations with faculty in various fields, while still developing deep knowledge depth in their chosen doctoral field. The majority of IGERT projects aim to develop students with mastery of one field who can work with scientists in other fields and use the techniques of multiple disciplines.

IGERT students are being prepared for a wide range of careers, with both academic training as well as experiences familiarizing students with careers outside the academy in industry or public laboratory settings. More IGERT students than non-IGERT students have worked on research projects with government laboratory scientists, industrial scientists, or faculty from other universities. IGERT students are also more likely to have opportunities to conduct off-campus internships lasting a month or more. These experiences leave IGERT students feeling more prepared for a broad range of careers, and ready to work in both academic and non-academic positions.

Finally, IGERT students are receiving the professional skills relevant to working in the 21st century. Significantly more IGERT than non-IGERT students report having received coursework or formal training in research ethics, professional speaking skills, communicating to the general public, and communicating outside their own discipline. IGERT students have engaged in many more team-oriented research and educational projects, including teams comprised of individuals from multiple disciplinary backgrounds. As a result IGERT students feel far more prepared to conduct research in an ethical manner, work in multidisciplinary teams, and communicate with people outside their own field.

Catalyzing a Cultural Change in Graduate Education

IGERT participants report evidence that the IGERT program is helping catalyze a cultural change in graduate education. IGERT projects have established innovative models for graduate education and training that transcend traditional disciplinary boundaries. IGERT faculty report much higher levels of interdisciplinary collaboration, research, and teaching than do non-IGERT faculty. While part of this difference may be a function of pre-existing differences between the two groups, there is evidence that participation in IGERT increases the interdisciplinary behavior of faculty. The act of organizing around an IGERT grant provides faculty members with increased opportunities for interdisciplinary collaboration, and many faculty members report that their IGERT participation has impacted their own professional lives, making both their teaching and research more interdisciplinary. Faculty report that the act of formalizing IGERT projects often energizes and catalyzes interest in the interdisciplinary theme. The existence of IGERT projects on campuses may also provide some protection to younger, untenured faculty members, who may otherwise feel less secure about branching out into interdisciplinary work before having earned tenure within a disciplinary department.

IGERT projects are catalyzing change within their host institutions through the creation of new courses and degrees, and the modification of policies, requirements, and programs. Both IGERT and non-IGERT faculty perceive that their institution's support for interdisciplinary research is stronger than that for interdisciplinary teaching. Still, nearly all IGERT PIs report that their institution's support for interdisciplinary graduate education has increased since their IGERT grant began, and that this increase is due in part to the presence of the IGERT grant. It is reasonable to hypothesize that, over time, the presence of IGERT interdisciplinary educational activities and programs will act as a catalyst to increase support for interdisciplinary graduate education. The ultimate impact of IGERT grants on institutional culture may depend in part on the ability of projects to sustain programmatic elements beyond the funding period. PIs are confident that they will be able to maintain opportunities to study multiple disciplines and access to disciplines and expertise outside of students' home departments for students who continue in IGERT-related programs. It may be this shift in educational philosophy—rather than other more tangible project elements—that remains, and which may have the greatest impact on the surrounding institutional culture.

Facilitating Diversity in Student Participation and Preparation

The IGERT program aims to facilitate diversity in student participation and preparation, and contribute to the development of a diverse, globally-engaged, science and engineering workforce. The IGERT program encourages diversity along a range of dimensions, including disciplinary background, viewpoints, training, ethnicity, and gender. The IGERT program has succeeded in increasing the number of American citizens enrolling in the nation's STEM doctoral programs,

individuals who have the potential to make strong contributions to the workforce. IGERT faculty members describe IGERT students as talented and enthusiastic. In spite of developing new doctoral programs, often from scratch, IGERT projects have been successful in recruiting women and minority students on par with national averages of the disciplinary fields represented in IGERT. Recognizing the importance of strengthening connections between IGERT graduate programs and earlier points along the educational pipeline, the NSF currently supports the IGERT National Recruitment Office, a stand-alone program dedicated to helping IGERT projects recruit individuals from underrepresented groups.

Directions for Future Research

The IGERT program represents a substantial investment in domestic graduate education, and new projects continue to be funded each year. As such NSF, the program community, and graduate education at large can benefit from continued evaluation and assessment of the IGERT program. As individuals begin graduating in larger numbers from IGERT projects, and grant funding draws to a close for many projects, there are several topics of investigation that might be of interest to the NSF and the graduate education community.

Assessment of Diversity Enhancement

Increasing the diversity of individuals entering STEM doctoral programs is an important goal of the IGERT program. One aspect of this diversity is enhancing access to STEM doctoral education for populations traditionally underrepresented in science (such as minority groups and women). Many IGERT projects have begun establishing recruitment relationships with programs or institutions that target individuals typically underrepresented in STEM fields. Future research could examine successful recruitment strategies, and the IGERT program's ability over time to recruit higher proportions of individuals from these groups. It could also examine how IGERT projects are broadening the pipeline, by forging linkages with Research Experiences for Undergraduates, undergraduate institutions, or other such connections.

Assessment of IGERT Graduate Career Outcomes

At the time this evaluation was conducted, only a handful of students had graduated from IGERT programs. By 2007-08 it is estimated that IGERT projects will graduate approximately 500 individuals each year, meaning that soon there will be thousands of IGERT graduates in the workforce. A longitudinal study of the career outcomes of IGERT graduates, to learn about their chosen career pathways, professional productivity and accomplishments, would be an important measure of the long-term impact of the IGERT program.

Assessment of IGERT Institutional Impacts

As the IGERT program evolves there will be opportunities to learn about continued institutional culture change and the lasting institutionalization of program elements. There are several possible methods of studying such impacts. First, this study primarily addresses questions of institutional impacts using data from IGERT participants. To learn more about the impact of IGERT projects on their host institutions, individuals external to the IGERT project but within the same institution could provide a useful perspective on IGERT and its impact.

Second, long-term institutional impacts and project sustainability can be examined after a project's funding has ended. While some of the IGERT projects examined in the Initial Impacts study had completed their funding period, many were just winding down. The current study provides baseline data on the perceptions of faculty and department chairs on institutional support for interdisciplinary graduate education. Future studies could collect data from other points in time, enabling a longitudinal analysis of institutional support and enabling conclusions to be drawn about the ways in which IGERT projects effect lasting change in their universities.

Assessment of the IGERT Model of Interdisciplinary Graduate Education

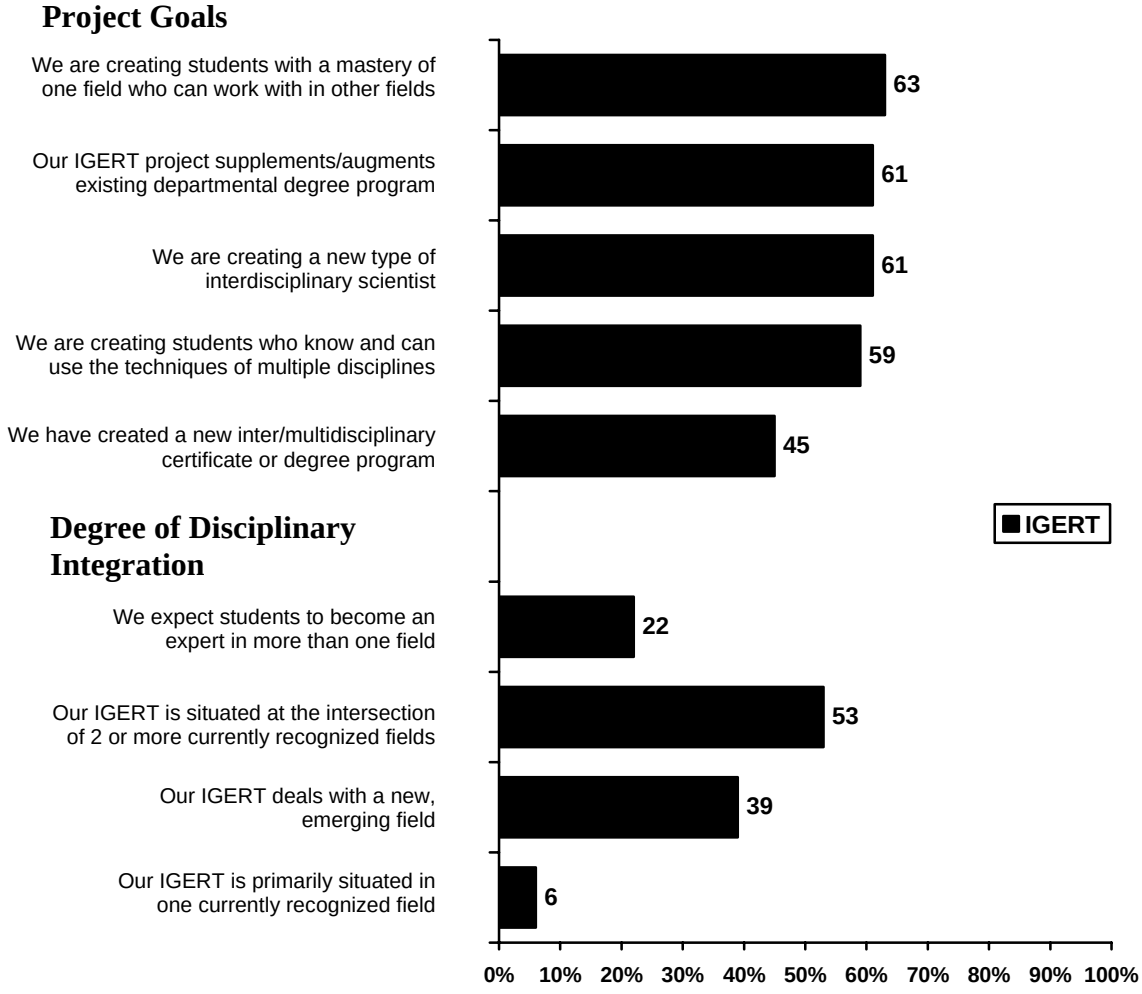
Finally, it would be possible to examine the IGERT model of graduate education itself. In what ways are IGERT activities "interdisciplinary" or "integrated"? What do these terms mean on IGERT campuses? How can the IGERT program help develop a broader understanding of what it means to engage in integrated and interdisciplinary graduate education? This study compared the IGERT model of education to that received in traditional single discipline programs. It did not examine other interdisciplinary graduate education programs, though there are other such programs scattered across American institutions. One could also examine the extent to which the IGERT model of education is the most effective means of reaching the goals of the IGERT program, or whether other interdisciplinary graduate education programs might better achieve the IGERT goals than does the IGERT program.

Appendix A: Supplementary Tables

IGERT Project Characteristics

Exhibit A.1

IGERT PI Descriptions of Their Projects



N=49

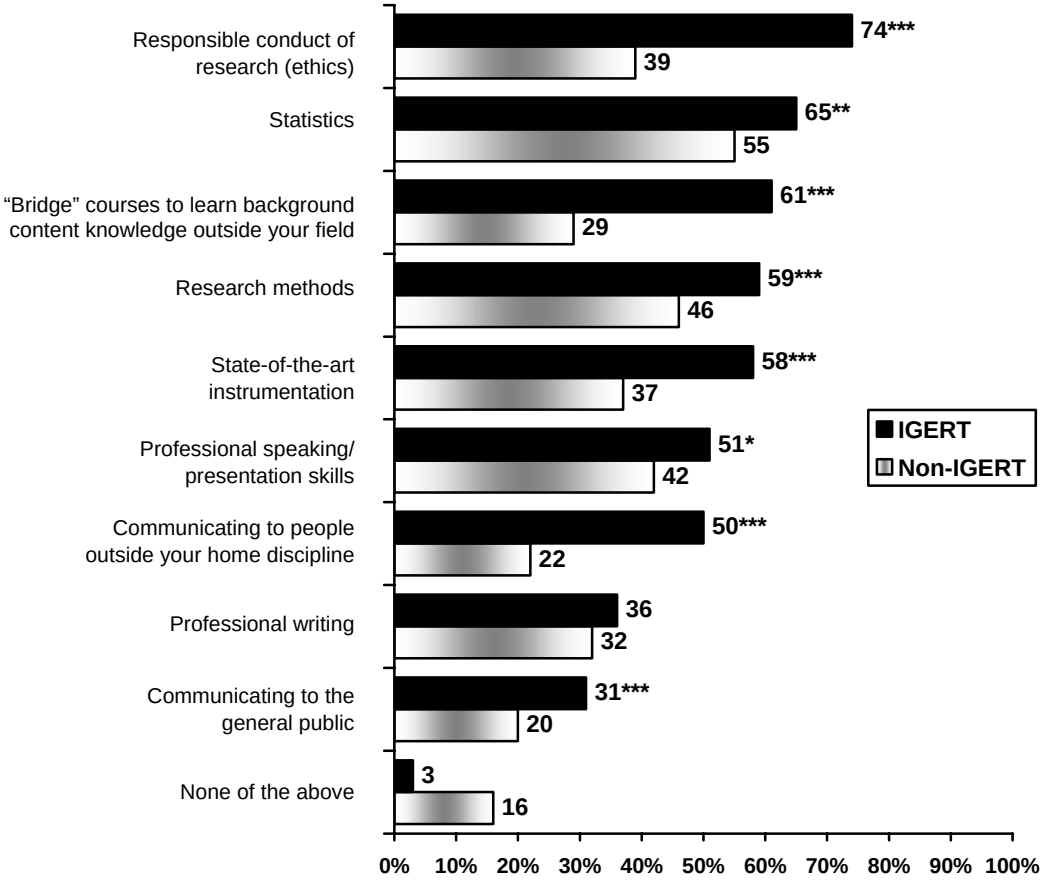
Note: Reporting the percent choosing "Completely" on a scale of 1 ("Not at all") to 5 ("Completely"). .

Source: Initial Impacts Survey of PIs 2004.

Question: "To what extent does each of the following statements describe the goals of your IGERT project?"

Exhibit A.2

Training and Coursework Received by IGERT and Non-IGERT Students



N IGERT Students=306. N Non-IGERT Students=566.

Note: Reporting the percent of students that agreed with each statement.

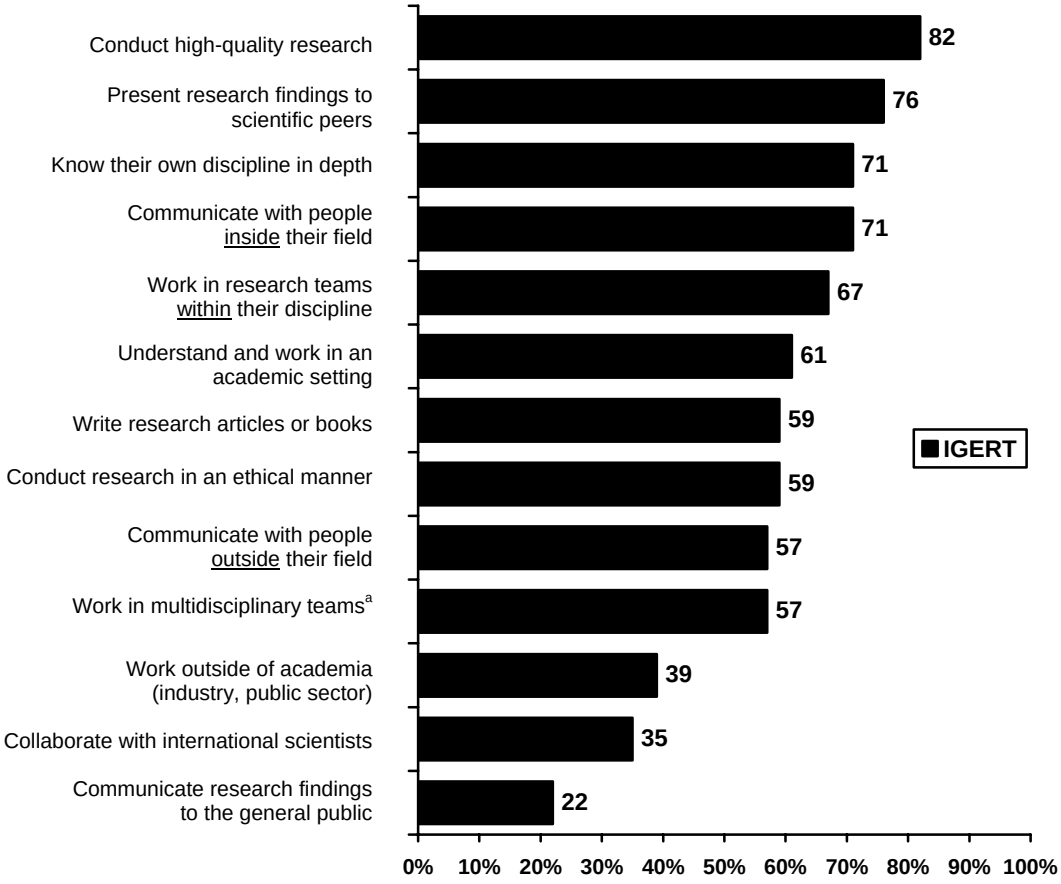
Source: *Initial Impacts Survey of Students 2004.*

Question: "Have you received formal training or taken courses in the following areas? 'Training' includes workshops, seminars, retreats, special sessions within a course, etc."

Exhibit A.3

PI Perceptions of Trainee Preparedness

"How well do you think your IGERT students are being prepared to…"



N =49.

Note: Reporting the percent choosing "Very Well Prepared" on a scale of 1 ("Not Well Prepared") to 5 ("Very Well Prepared").

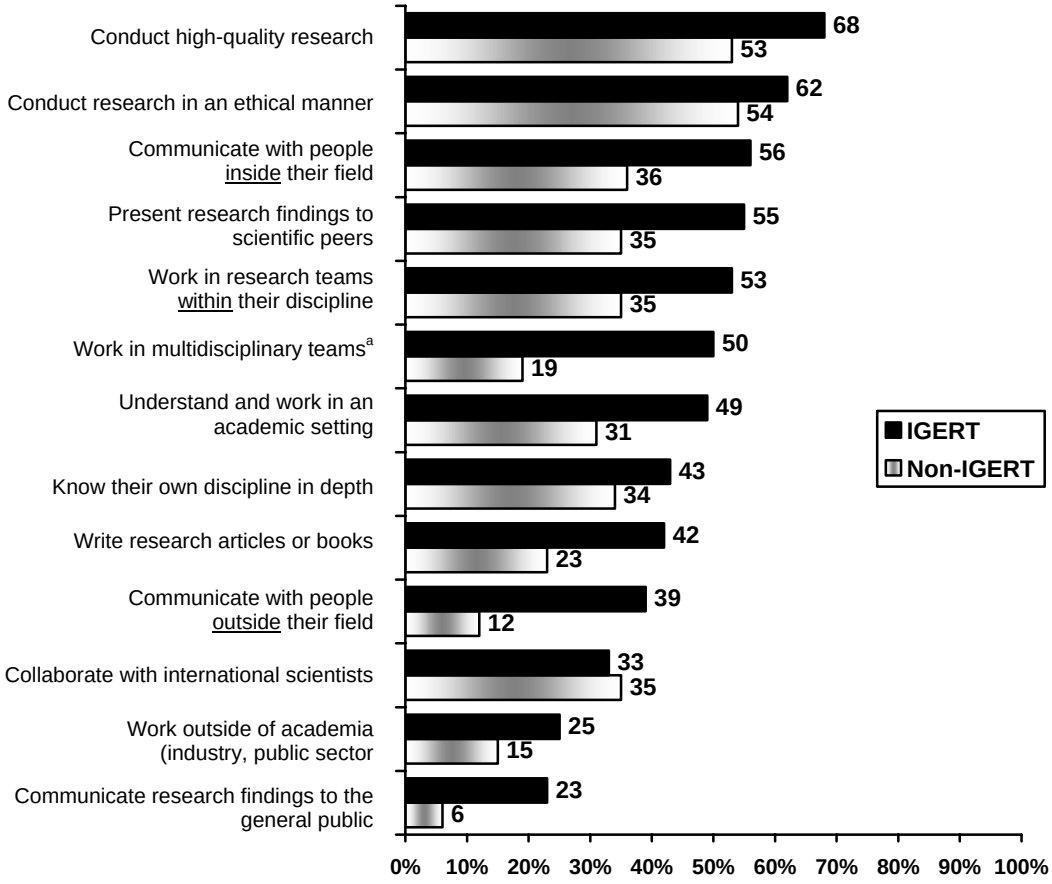
[a] Multidisciplinary teams = teams of researchers from more than one discipline

Source: *Initial Impacts Survey of PIs 2004.*

Question: "How well do you think your IGERT graduate students are being prepared for the following tasks?"

Exhibit A.4

Faculty Perceptions of Student Preparedness



N IGERT Faculty=347. N Non-IGERT Faculty=556.

Notes: IGERT faculty are reporting on their IGERT graduate students. Non-IGERT faculty are reporting on their own graduate students.

Reporting the percent choosing "Very Well Prepared" on a scale of 1 ("Not Well Prepared") to 5 ("Very Well Prepared").

[a] Multidisciplinary teams = teams of researchers from more than one discipline

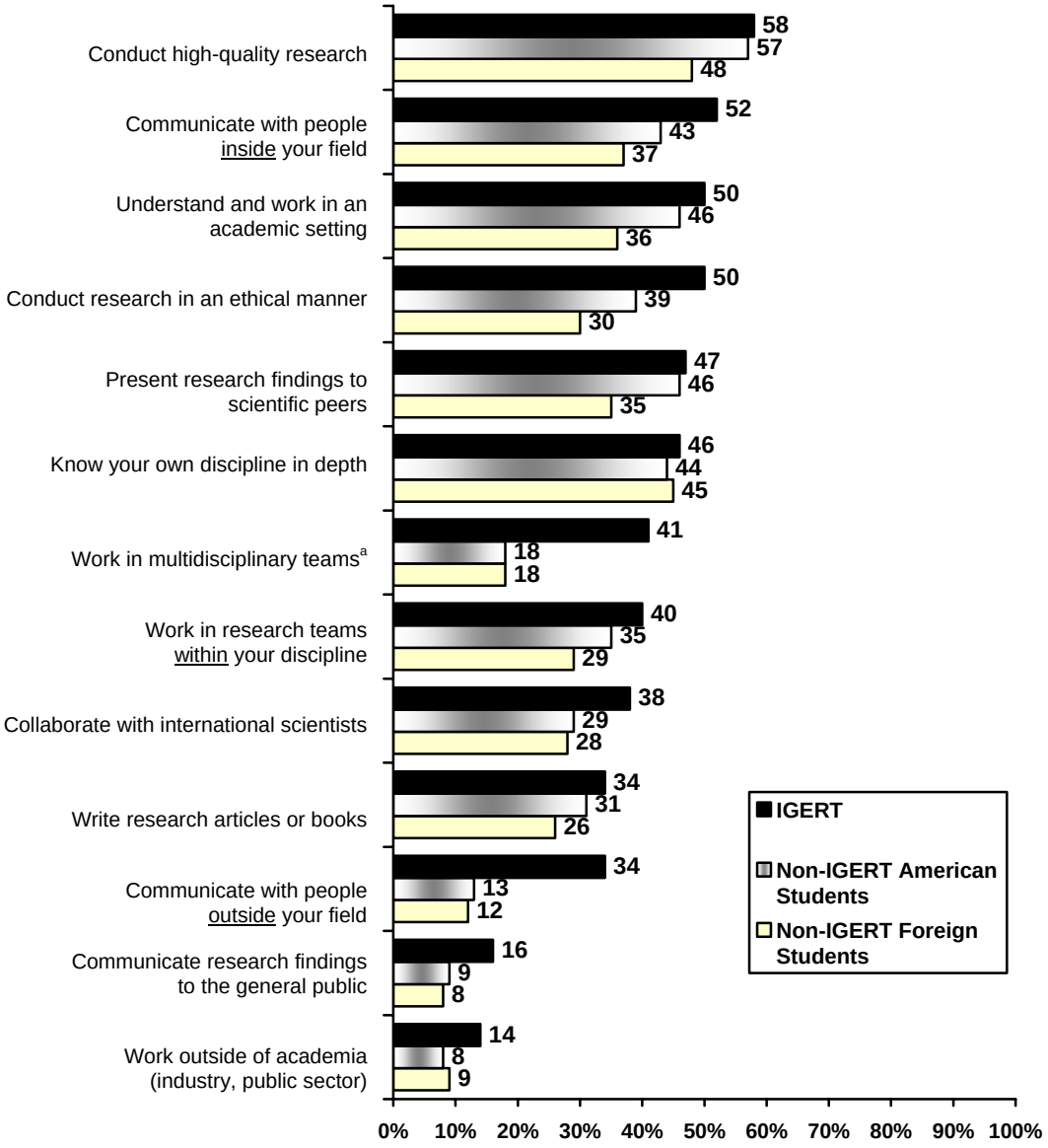
Source: *Initial Impacts Survey of Faculty*

Question: "How well do you think your IGERT graduate students are being prepared for the following tasks?" (IGERT faculty)
"How well do you think your graduate students are being prepared for the following tasks?" (Non-IGERT faculty)

Exhibit A.5

Student Perceptions of How Well Their Program is Preparing Them

"How well has your program prepared you to…"



N IGERT Students=306. N Non-IGERT American Students=343. N Non-IGERT Foreign Students=223.

Note: Reporting the percent choosing "Very Well" on a scale of 1 ("Not Well") to 5 ("Very Well").

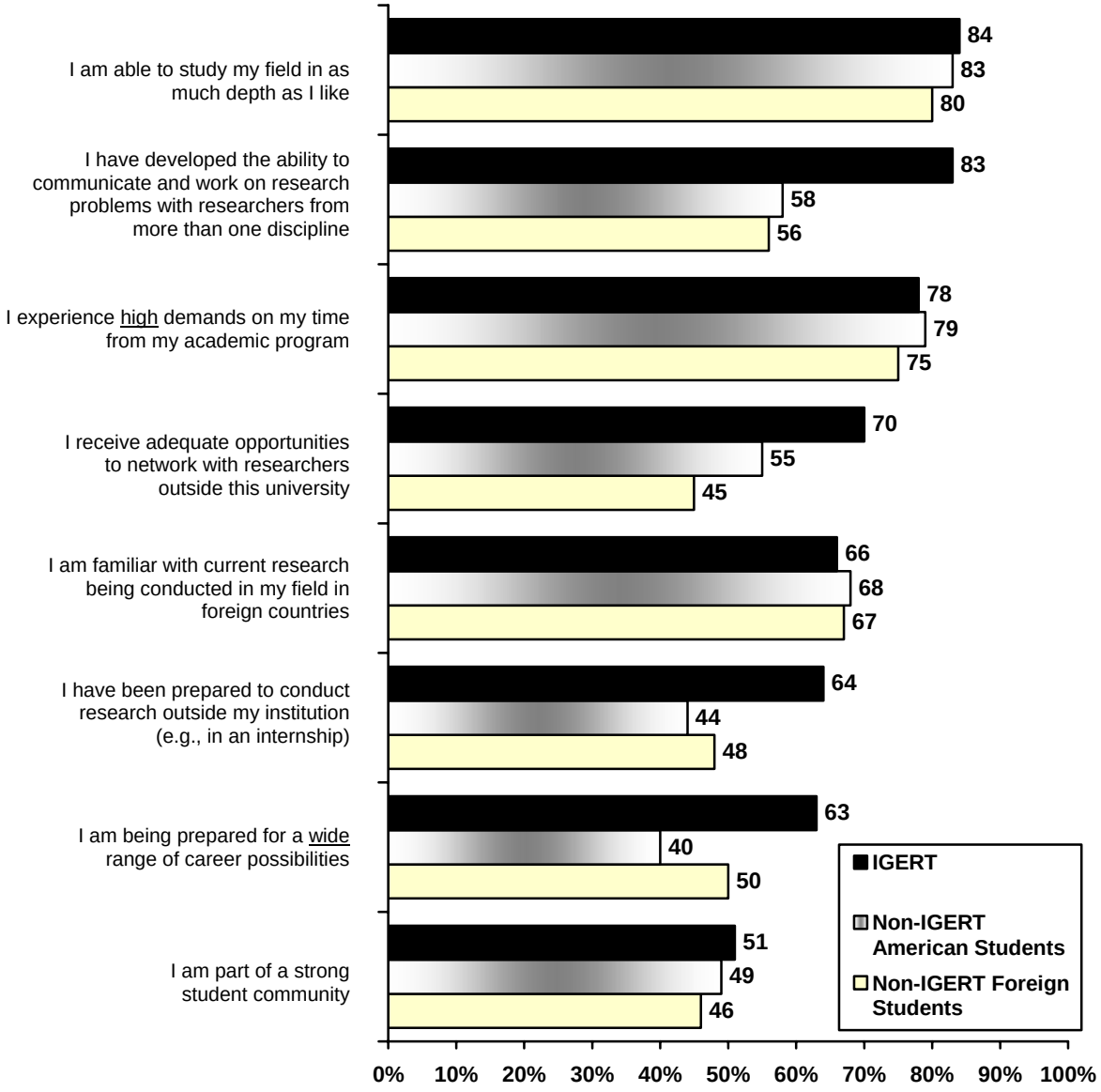
[a] Multidisciplinary teams = teams of researchers from more than one discipline

Source: Initial Impacts Survey of Students 2004.

Question: "On a scale of one to five, how well do you think your graduate program is preparing you for the following tasks?"

Exhibit A.6

Student Perceptions on Their Program



N IGERT Students=306. N Non-IGERT American Students=343. N Non-IGERT Foreign Students=223.

Note: Reporting the percent of students that agreed with each statement.

Source: Initial Impacts Survey of Students 2004.

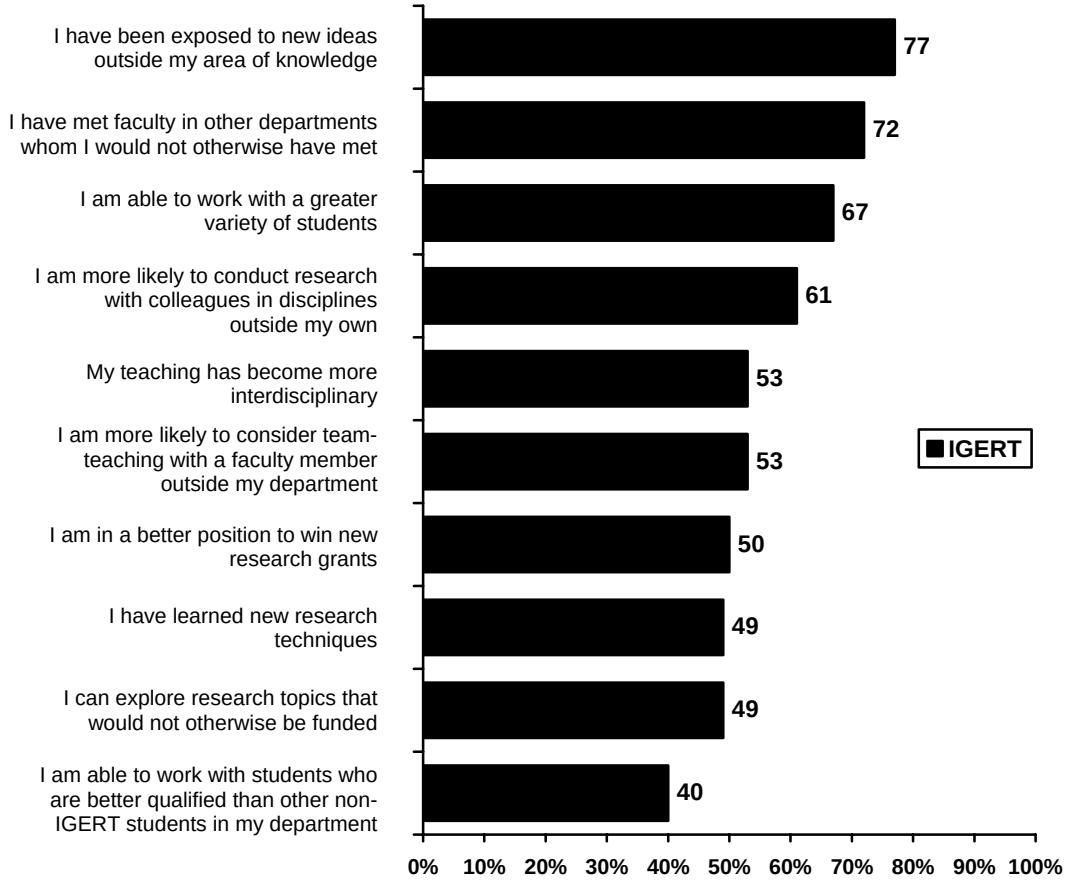
Question: "Please indicate the extent to which you agree or disagree with the following statements."

Impact of IGERT on Participating Faculty

Exhibit A.7

Faculty Reported Impacts of Participating in IGERT

"As a result of IGERT…"



N IGERT Faculty=344 (missing=3).

Source: *Initial Impacts Survey of Faculty 2004.*

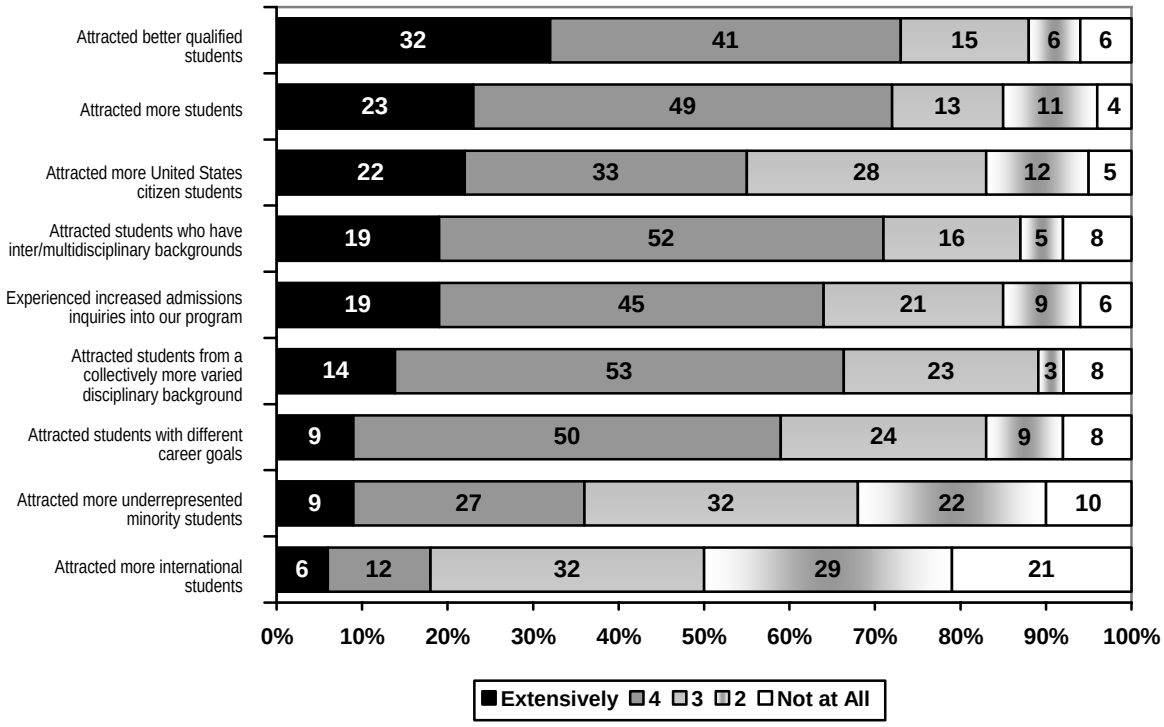
Question: "To what extent do you agree or disagree with the following statements about the impact that participating in the IGERT project has had on your professional life?" Respond on a scale of 1 ("Strongly Disagree") to 5 ("Strongly Agree"). Reporting the percent choosing '4' or '5'.

Impact of IGERT on Departmental Admissions

Exhibit A.8

IGERT Department Chair Perceptions of the Impact of IGERT on Departmental Admissions

"As a result of IGERT, we have…"



N = 78 (missing=7).

Source: Initial Impacts Survey of Department Chairs 2004.

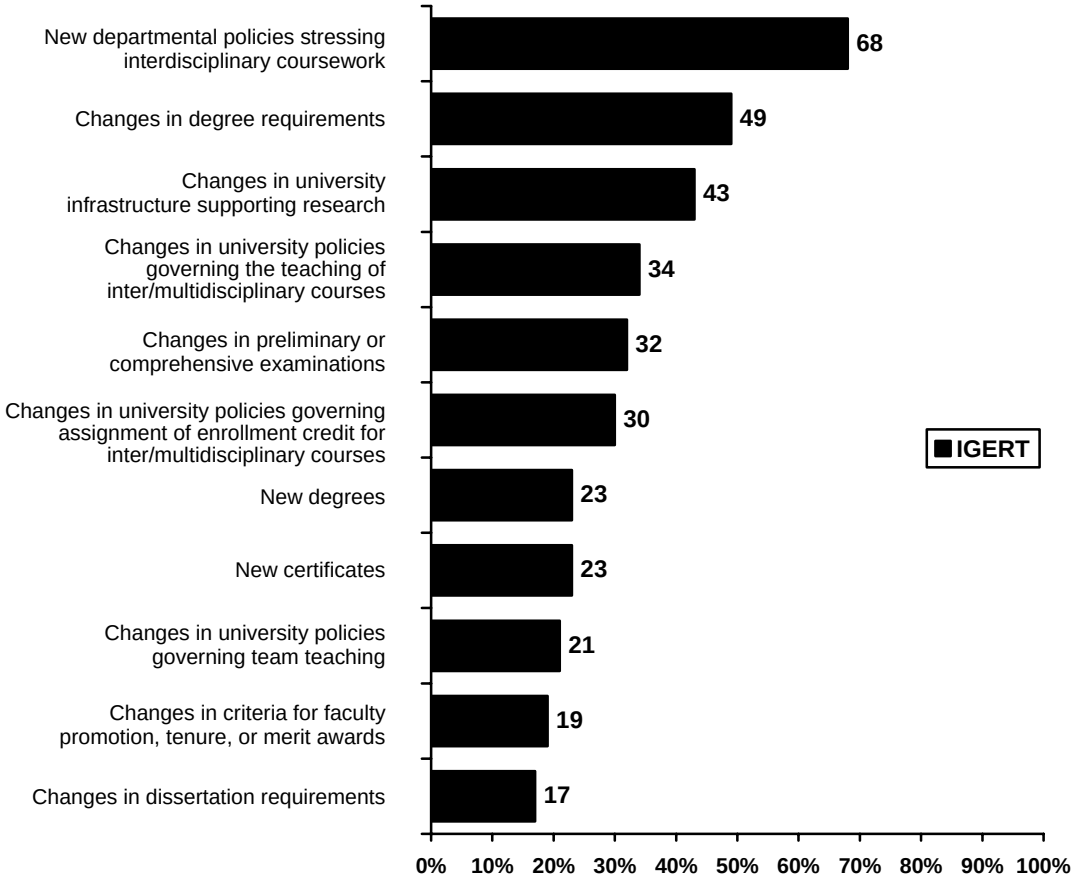
Question: "Has the presence of the IGERT grant had an impact on your departmental admissions in any of the following ways?"

Institutional Impact of IGERT

Exhibit A.9

PI Reports of Project Impact

"The IGERT Project has resulted in…"



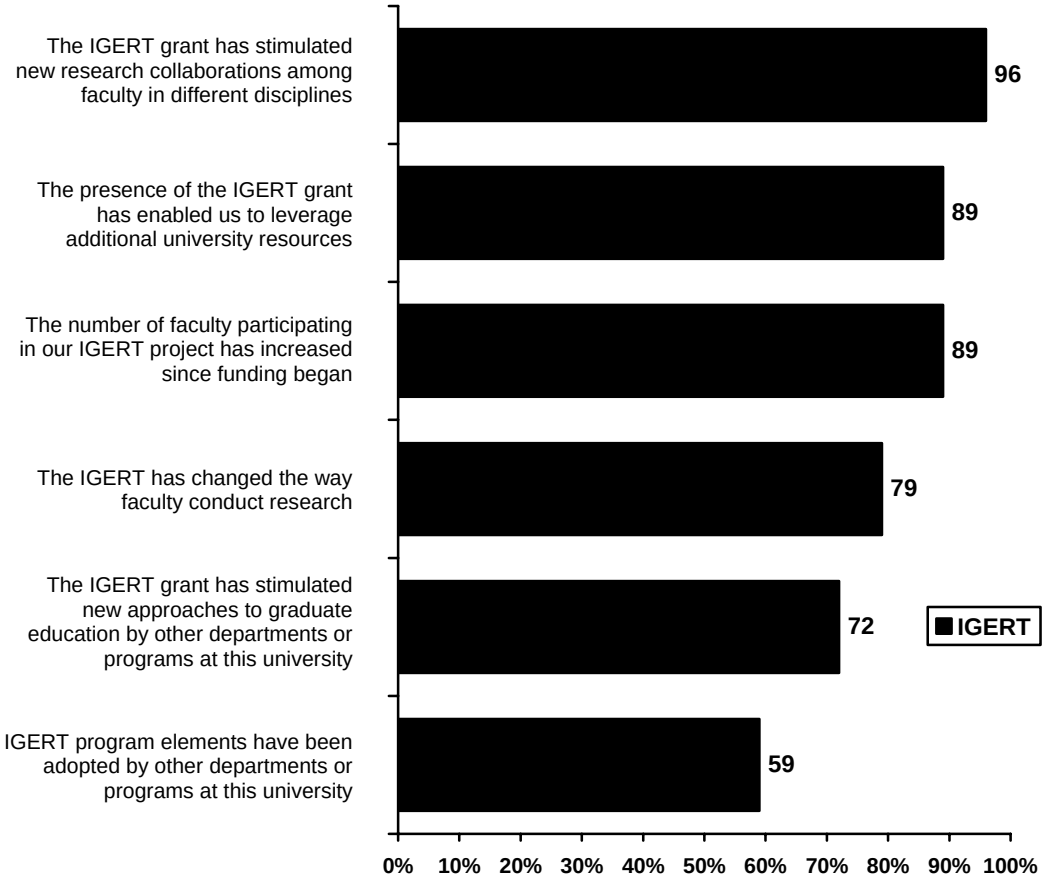
N IGERT PIs=47 (missing=2).

Source: Initial Impacts Survey of PIs 2004.

Question: "Has the IGERT grant resulted in any of the following changes at your university (or other universities participating in your project)?"

Exhibit A.10

PI Perceptions of Project Impact



N IGERT PIs=47 (missing=2).

Source: *Initial Impacts Survey of PIs 2004.*

Question: "Has the IGERT grant resulted in any of the following changes at your university (or other universities participating in your project)?"

Appendix B: Bibliometric Analysis

As part of the Initial Impacts Evaluation, curricula vitae (CVs) were requested from all participating IGERT and non-IGERT faculty members. Ultimately, 350 IGERT and 252 non-IGERT faculty members provided their CVs. Publication information from each CV for the years 1999 through 2003 was extracted, coded, and analyzed by ipIQ, a subcontracting firm hired to conduct the analysis. The purpose of the analysis was to examine the publication and citation patterns of IGERT and non-IGERT faculty members, with a focus on their interdisciplinary publication and citation behavior. The following report summarizes findings from the analysis.

IGERT Initial Impacts Study: Bibliometric Analysis

FINAL REPORT

PREPARED FOR ABT ASSOCIATES, INC.

JENNIFER CARNEY, PH.D.

DEEPIKA CHAWLA, PH.D, ED.D.

April 4, 2005
Prepared by:

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TABLE OF CONTENTS

Introduction

ipIQ (formerly CHI Research, Inc) is pleased to present this study to Abt Associates. The study looks at faculty members who participate in the *Integrative Graduate Education Research and Traineeship Program* (IGERT), managed by the National Science Foundation's Directorate for Education and Human Resources, Division of Graduate Education. The IGERT program was specifically designed to educate doctoral students in a multidisciplinary setting.

To analyze the effects of the IGERT program, ipIQ compared a set of authors that have participated in the IGERT program (the IGERT authors) with a similar set of authors that have not participated in the program (the Control authors).

The study looked to answer the following questions:

1. Did the IGERT program have an effect on the participants' productivity? ipIQ did not find an appreciable difference in the number of publications between the two groups.

2. Are the IGERT authors more likely to publish in an area outside their own discipline than the Control authors? We found mixed results. In certain disciplines–such as Biology, Psychology, Mathematics, and Humanities–the IGERT authors are clearly more likely to cross disciplines; but in others, the opposite is true. In many respects, an interdisciplinary approach is already the norm among American Universities.

3. Have the IGERT authors had a greater impact in their publications? The answer is clearly "yes." IGERT authors are more highly cited every year, and the trend persists in every discipline except Social Science. The effect is most noticeable among the IGERT authors in Earth and Space, and Biology. Furthermore, the IGERT authors are more highly cited than Control authors regardless of which fields they publish in.

4. Are the IGERT authors more likely to reference material outside of their disciplines? Here again, the results are mixed, but the effect is most noticeable among authors in Biology, Psychology, Mathematics, and Humanities. This may be related to the fact that in these disciplines, more than in others, authors are likely to publish outside their main fields, and thus self-referencing may be a factor.

5. Do the IGERT authors obtain a higher number of authorships on their publications? There is no clear indication of this. A paper published by an IGERT author contains roughly the same number of institutions and departments as a paper published by a Control author.

Procedure

ipIQ (formerly CHI Research, Inc.) compared the publication characteristics of two groups of authors, those that participated in the National Science Foundation's *Integrative Graduate Education Research and Traineeship Program* (the IGERT authors) and those that did not participate (the Control authors).

Obtaining Data

ipIQ obtained a set of 602 Curriculum Vitae (CV), 350 from IGERT authors, and 252 from Control authors. Of these, there were 9 CVs that could not be read – 6 from IGERT authors and 3 from Control authors – and they were immediately dropped from the study. This left us with 344 CVs from the IGERT group, and 249 from the Control group.

Extracting Publications

A machine-readable CV was stripped of all information except the publications of the authors. All publications, both those of the IGERT and Control groups, were tagged with the author's IGERT number and Respondent ID as they appeared on the CV. The Respondent ID was used to determine the author's discipline.

For example, the CV for a typical respondent might have produced the following table of publications (the data are not actual data):

IGERT	RespID	Publications
9870631	11652	The Role of the Spinodal Region in One-Dimensional Models of Phase Transformations (with A. Vainchtein, P. Rosakis & L. Truskinovsky), Physica D 115 (1998) 29-48.
9870631	11652	Stability of Axial Motions of Strings, ZMAP 47 (1996) 809-816.
9870631	11652	Bifurcation and Metastability in a New One-Dimensional Model for Martensitic Phase Transitions (with A. Vainchtein & P. Rosakis), Comput. Meth. Appl. Mech. Engr. 170 (1999) 407-421.
9870631	11652	Global Continuation via Higher-Gradient Regularization and Singular Limits in Forced One-Dimensional Phase Transitions (with H. Kielhöfer) SIAM J. Math. Anal. 31 (2000) 1307-1331.
9870631	11652	Nonlinear Standing and Rotating Waves on the Sphere (with C. Gugg, S. Maier-Paape & H. Kielhöfer), J. Differential Equations 166 (2000) 402-442.
9870631	11652	On 2D Steady Solutions of the Planar Couette Flow Problem (with P. Mehta), manuscript, 2004.

A technical assistant then went through all references and deleted those that did not fit within the years of the study, 1999 to 2003. The table above would have lost the first reference (since it is dated prior to 1999) and the last (since it is dated after 2003). The resulting shorter table looked like this:

IGERT	RespID	Publications
9870631	11652	Stability of Axial Motions of Strings, ZMAP 47 (1996) 809-816
9870631	11652	Bifurcation and Metastability in a New One-Dimensional Model for Martensitic Phase Transitions (with A. Vainchtein & P. Rosakis), Comput. Meth. Appl. Mech. Engr. 170 (1999) 407-421
9870631	11652	Global Continuation via Higher-Gradient Regularization and Singular Limits in Forced One-Dimensional Phase Transitions (with H. Kielhöfer) SIAM J. Math. Anal. 31 (2000) 1307-1331
9870631	11652	Nonlinear Standing and Rotating Waves on the Sphere (with C. Gugg, S. Maier-Paape & H. Kielhöfer) J. Differential Equations 166 (2000) 402-442

Continuing like this, we created a table of 7493 publications between the years 1999 and 2003.

UNIFYING PUBLICATIONS

The table was sent through ipIQ's standard process of unification, in which a technical assistant assigns to each reference the following fields:

- **Type**: "S" if the reference is to a paper appearing in a refereed Scientific journal; "O" otherwise. If the Type is "S", then the following fields were also included:
- **Year**: The year of the article's publication.
- **Journal**: The refereed journal of publication, such as such as *Science,* or *The American Journal of Physiology*
- **Author**: The first 6-characters of the first author of the article.
- **Page**: The first page of the article.
- **Volume**: The volume of the article.

After the unification process the table above looks like this, complete with the added fields.

IGERT	RespID	Publications	Type	Year	Journal	Author	Page	Volume
9870631	11652	Stability of Axial Motions of Strings, ZMAP 47 (1996) 809-816	O					
9870631	11652	Bifurcation and Metastability in a New One-Dimensional Model for Martensitic Phase Transitions (with A. Vainchtein & P. Rosakis), Comput. Meth. Appl. Mech. Engr. 170 (1999) 407-421	S	1999	COMPUT METH	VAINCH	407	170
9870631	11652	Global Continuation via Higher-Gradient Regularization and Singular Limits in Forced One-Dimensional Phase Transitions (with H. Kielhöfer) SIAM J. Math. Anal. 31 (2000) 1307-1331	S	2000	SIAM J MATH	KIELHO	1307	31
9870631	11652	Nonlinear Standing and Rotating Waves on the Sphere (with C. Gugg, S. Maier-Paape & H. Kielhöfer) J. Differential Equations 166 (2000) 402-442	S	2000	J DIFF EQUA	UGG	402	126

There are two important points that should be made about the table above:

1. The first publication was given a type "O", since it does not appear in a standard refereed journal. We have no information on the journal *ZMAP*, and despite the title of the article, we have to assume it is not a scientific paper. In any case, it cannot be used in any further analysis, because we cannot obtain the journal's field.

2. It is not certain that the author listed in the unified fields is, in fact, the first author of the paper. For every publication, it may be that the first author was the author of the CV, and only the co-author was mentioned in the reference. This does not cause a problem, since we can, at a later point, substitute the CV-author for the listed author just by translating the Respondent ID. In the above table, the Respondent ID leads us to assume that the first author, in every publication, may be "HEALY," the author of the CV.

After unification, we found there were 6834 publications that were of type "S" and between the years 1999 and 2003.

PURCHASING ARTICLE INFORMATION FROM ISI

Using the unified information from the above table, we created standard keys to ship to the Institute for Scientific Information (ISI), so that further information about the articles could be gotten from their databases. For each publication, we created two keys: One with the first listed author, and a second with the CV-author. In cases in which the first listed author and the CV-author were the same, we created only one

key. It is not possible for both keys to match in the ISI database. In all we created 11,983 keys.

In work of this sort, it is always possible that a valid key will not match. This usually happens because of misinformation in the reference itself. For example, a page may be wrongly cited, or an author's name may be misspelt. Of the 6834 references that were used in the study, a full 5306 (or 78%) were matched to ISI's database, which is a very good match rate based on our experiences.

With ISI's data, we assigned to each publication the following field.

1. The K-code (see Table 1)
2. The Journal Field (see Table 2)
3. The references from the paper.
4. The citations to the paper.
5. The institutional addresses of the authors.

FILTERING BASED ON ISI'S DATA

The K-code is used to filter out those publications that are not articles, notes, and reviews. Other types of publications (for example, book reviews or editorials), are not considered scientific references and do not have fields assigned to them, and therefore lie outside the scope of this study. Of the 5306 matched papers, 5147 are articles, notes, and reviews and remained in the study.

SUMMARY

The table below brings together a great deal of information about the procedure of the study.

		IGERT-Authors	Control-Authors	Total
A	No. of CVs	350	252	602
B	No. of Valid CVs	344	249	593
C	No. of Papers in "B" published between 1999 and 2003	4433	3060	7493
D	No. of Papers in "C" of type "S" (Papers published in a scientific journal)	3861	2973	6834
E	No. of Papers in "D" that matched to the ISI database	3021	2285	5306
F	No. of Papers in "E" that were articles, notes, reviews	2926	2221	5147

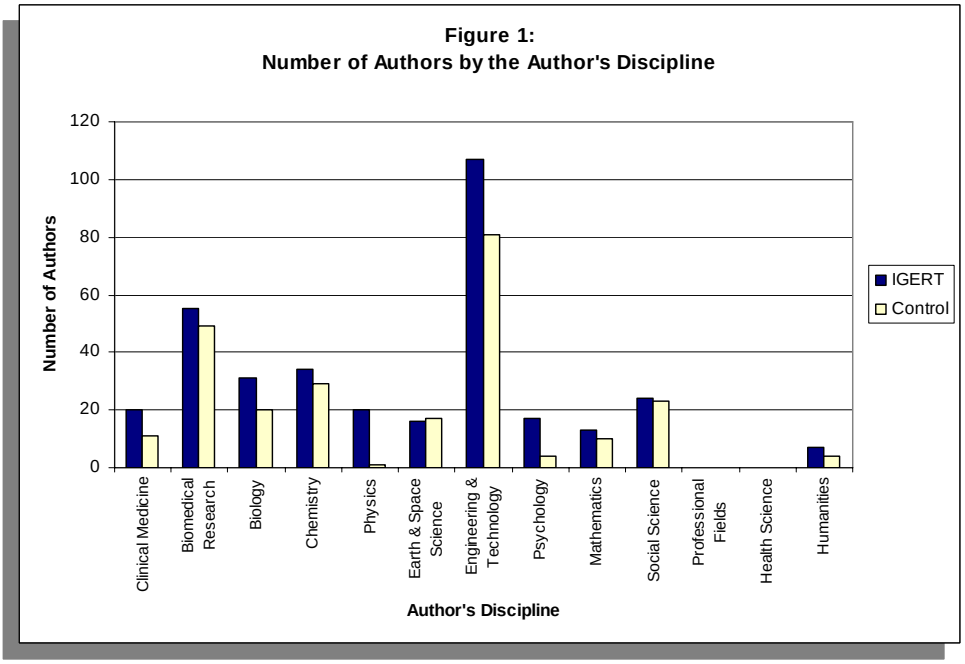
Results

PRELIMINARIES

In all there were 344 IGERT authors and 249 Control authors used in the study, or nearly 100 more IGERT than Control authors. The distribution is a little uneven. Although the unevenness is not so great that it can immediately invalidate the study, it is a fact that should be kept in mind as the results unfold.

To get a further handle on the differences, Figure 1 shows the number of authors in each group by the discipline of the author (see also Table 3). The biggest difference is in Physics (20 IGERT vs. only 1 Control author), and in Engineering and Technology (107 IGERT vs. 81 Control authors).

Figure 1:
Number of Authors by the Author's Discipline



PUBLICATIONS

The most obvious use of publication data is to measure an author's productivity. Using this measure, we can ask if the IGERT program has had a positive, negative, or possibly neutral effect on a participant's output.

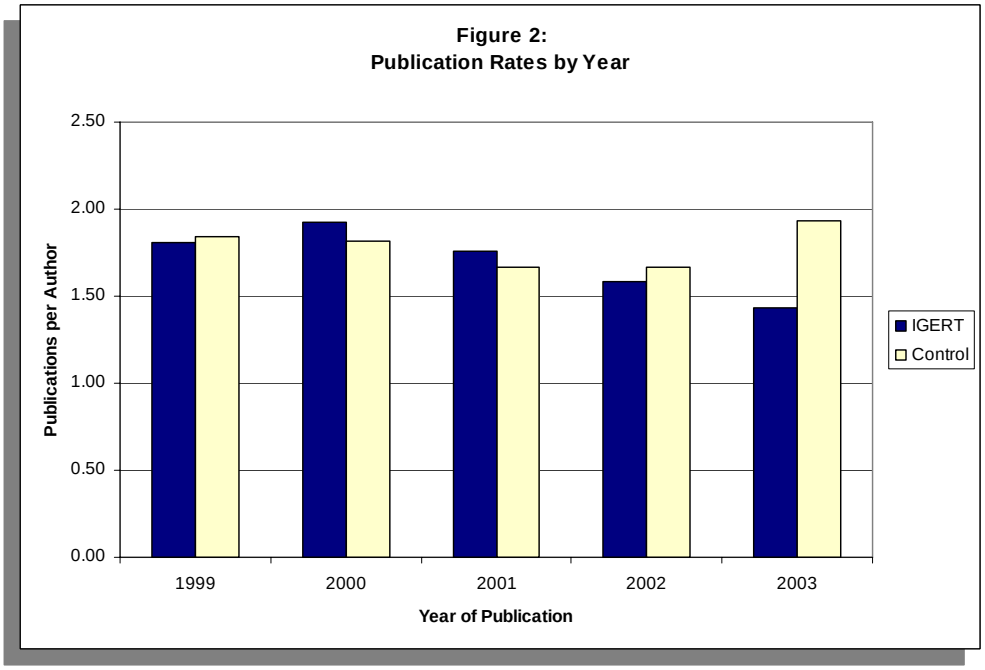
Another, less obvious, use of publication data is to measure an author's scope of research. In this way, we can see if IGERT authors are more or less likely to move across disciplines in their research. Encouraging an interdisciplinary approach is one of the major purposes of the IGERT program, and this is the first of three ways in which we will try to see if the program has been successful.

THE FREQUENCY OF PUBLICATIONS

This section will compare the publication rates of the two groups of authors. All data will be presented as publications per author, in order to control for the different sizes of the two groups.

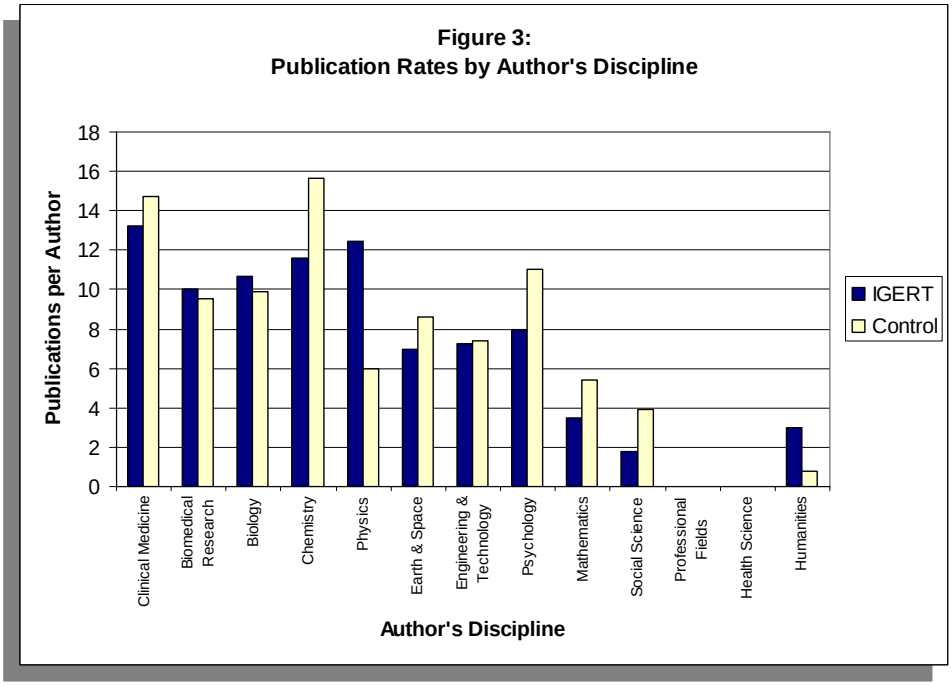
Overall, looking at the complete database of 5 years (1999 to 2003) and all disciplines, the IGERT group has published about 8.5 papers per author while the Control group has published about 8.9 papers per author. We can break down the data further. Figure 2 compares the publication rates across the publication years, for all disciplines combined (see also Table 4):

Figure 2:
Publication Rates by Year



The figure does not show any tendency for one group to publish more than another.

In order to see if there is an effect within a specific discipline that is being hidden in the yearly data, Figure 3 makes a similar comparison for each discipline across all publication years combined (see also Table 5):



Again, neither figure shows a strong trend of one group being more prolific than the other.

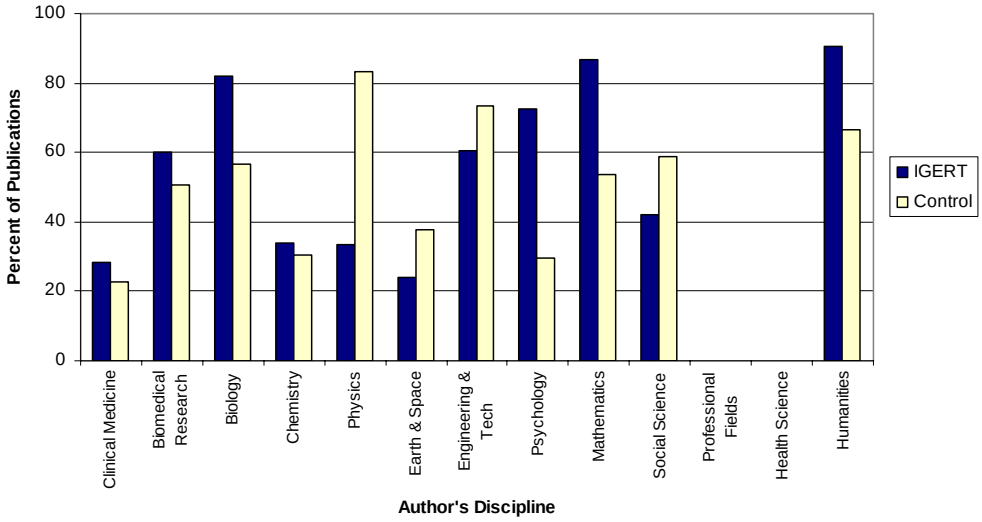
THE FIELDS OF PUBLICATIONS

This section will compare the contents of the publications of the two groups of authors; in particular, we are interested in seeing if the authors of the IGERT group are more likely to publish outside their chosen discipline than are the authors of the Control group. This will give us a sense of the multi-disciplinarity of the two groups. To make this comparison, we use the percent of each group's publications that appear in a scientific field outside the author's discipline. Overall, 53.6% of all IGERT publications were published outside the author's discipline, compared with 50.5% of all Control publications.

We can break down the data by the author's discipline. For example, consider first the IGERT group. We know that there are 20 authors in this group that are working in the discipline of Clinical Medicine. These authors have published a total of 264 papers. Of these, 75 (or 28.4%) have appeared in fields outside of Clinical Medicine. In the Control group, there are 11 authors in Clinical Medicine, who have published 162 papers, and 37 (or 22.8%) appear outside of Clinical Medicine. The two groups are essentially equal in this case.

Full information may be found in Figure 4 (see also Table 6). The picture is mixed. In certain disciplines (such as Biology, Psychology, and Mathematics and Humanities), the IGERT authors show a greater tendency to publish outside their disciplines than do the Control authors. In other disciplines (most notably Physics), the reverse is true.

Figure 4:
Percent of Publications Outside Author's Discipline



There are many ways to use publications to measure the interdisciplinary approach of authors. Another view is achieved not by counting publications themselves, but the number of authors who have published outside their disciplines. To do this, we have assigned each author to one of four discipline types:

1. Single Field Authors: Researchers who publish only within own their own fields, and only within one subfield.

2. Multiple Subfield Authors: Researchers who publish only within their own fields, but in multiple subfields.

3. Multiple Field Authors: Researchers who publish within their own field and in other fields.

4. Outside Field Authors: Researchers who publish only outside their own fields.

Figure 5a plots the percentage of authors who fall in each of these four discipline types, and Figure 5b plots the percentage of publications (see also Table 7). Again, there is no difference between the two groups. In both groups, the preponderance of publications were written by authors in type 3, that is, most authors publish papers (approximately 85% of each group) both in their own discipline and in others. An interdisciplinary approach is already the norm among faculty members, even those outside the IGERT program.

Figure 5a:
Percent of Authors in the four Discipline Types

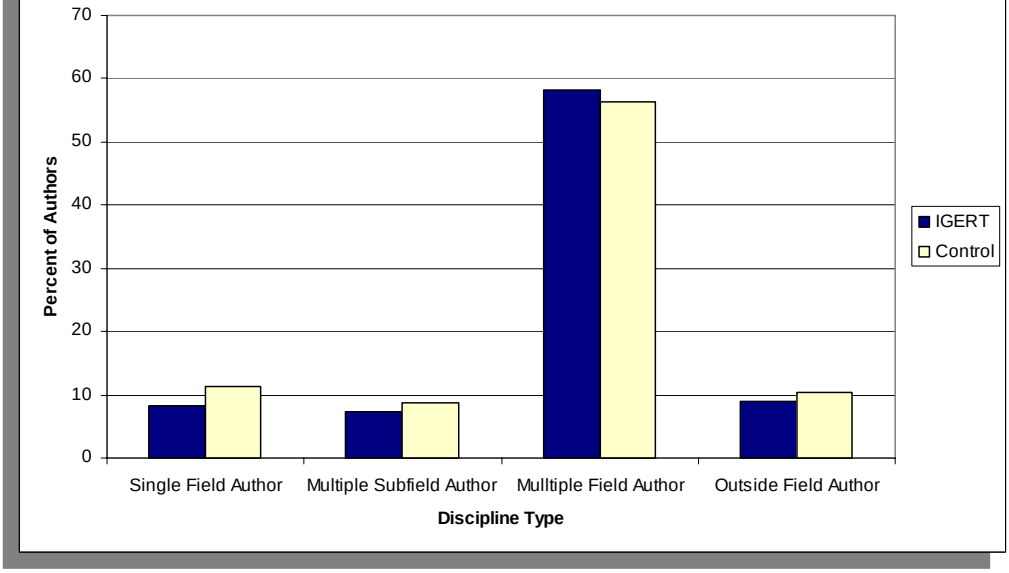
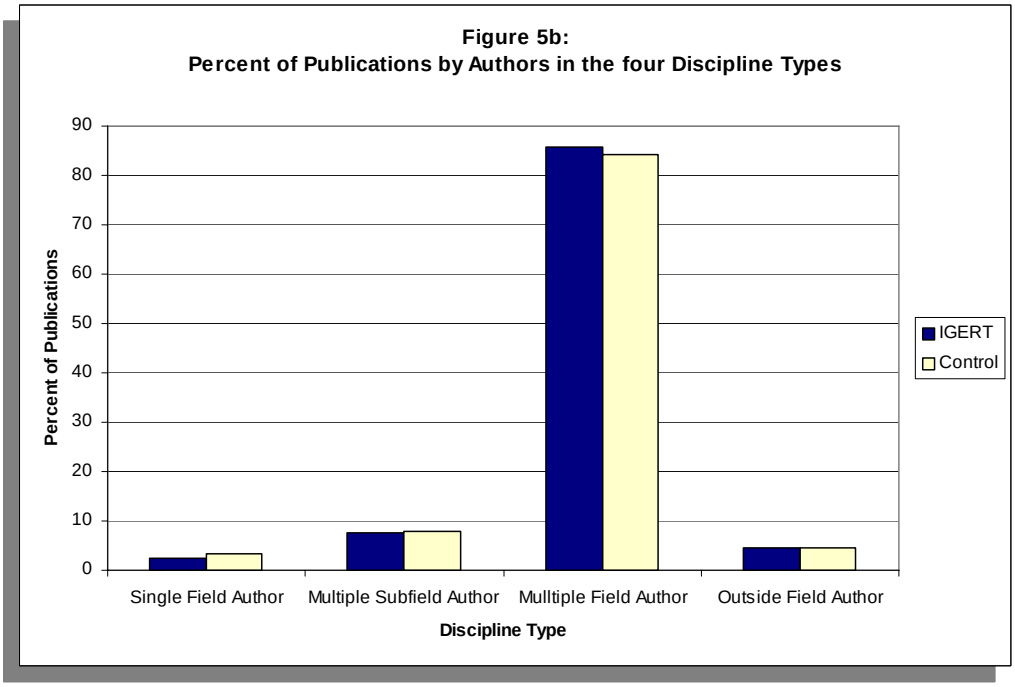
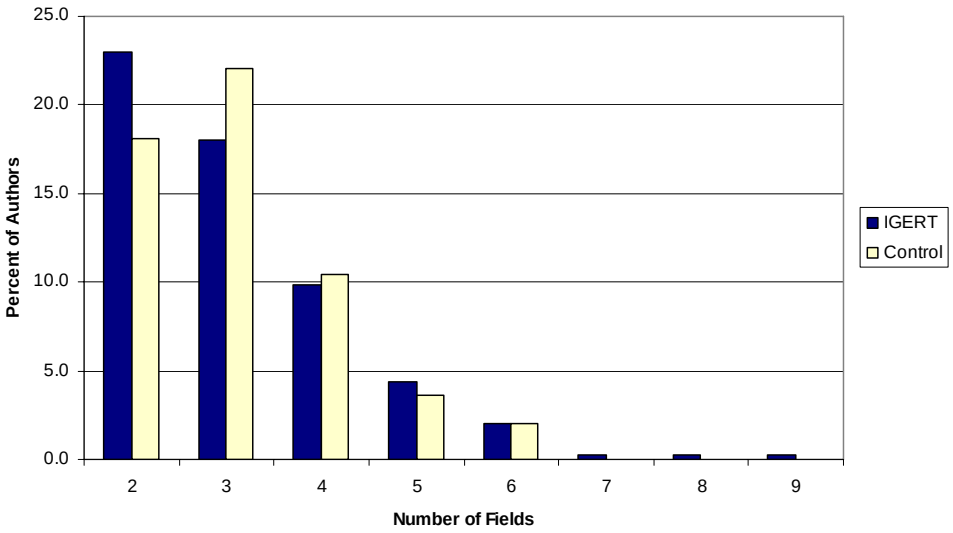


Figure 5b:
Percent of Publications by Authors in the four Discipline Types



We can also calculate the spread of disciplines between the two groups. Overall, 41.9% of all IGERT authors, and 43.8% of all Control authors, publish in only one field. The percent of authors who publish in two or more fields is shown in Figure 6 (see also Table 8).

Figure 6:
Interdisciplinary Spread



CITATIONS

A citation is a reference from one publication to a previous publication. As such, the citation creates a link between the two publications.

The meaning of the link depends on the direction in which we decide to view it. When viewed by the author who is receiving the reference, the citation is a measure of the author's influence on subsequent research; analyzing these citations will define an author's impact.

When viewed by the author who is referencing a previous work, the citation declares the history on which the author is basing his research; analyzing these references will define the scope of an author's research interests. This will give us a second opportunity to examine the effect of the IGERT program on a participant's interdisciplinary research.

In this study, citations are from all years ending 2004, but the nature of ISI's data is that a few citations from 2005 are also present.

COMPARISON OF IMPACT

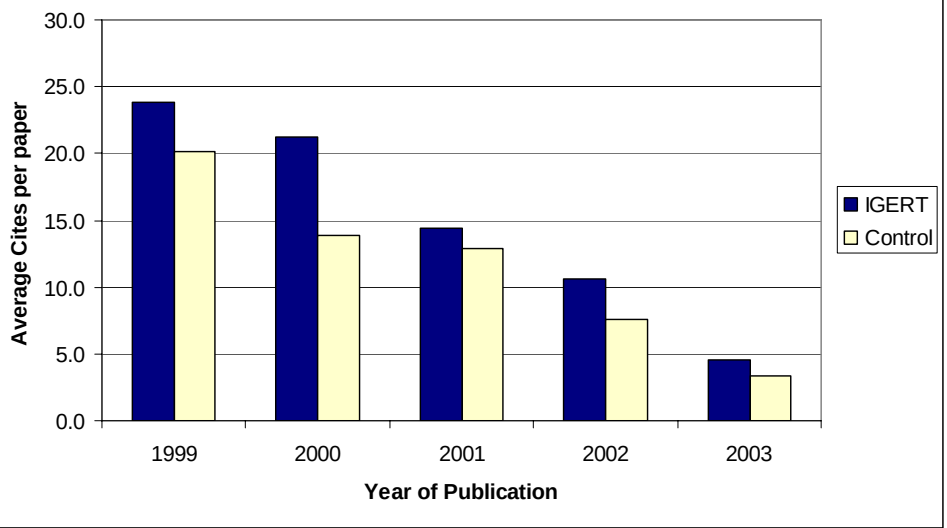
Citations are issued only to publications that are deemed important. In this way the number of citations per publication is a measure of impact. Citation counts, however, must always be normalized in two ways:

1. By the year of publication, since older papers have more time to be cited.
2. By the field of publication, since some fields, like Biomedical Research, will receive more citations than other fields, like Health Science.

We know that the IGERT authors and the Control authors do not appreciably differ in terms of the number of publications, but this section will show that there is a noticeable and persistent trend for the IGERT authors to receive more citations than the Control authors. Otherwise stated, this means that the IGERT authors generally have a higher scientific impact than others. The nature of the impact is not overly great, but it is certainly persistent.

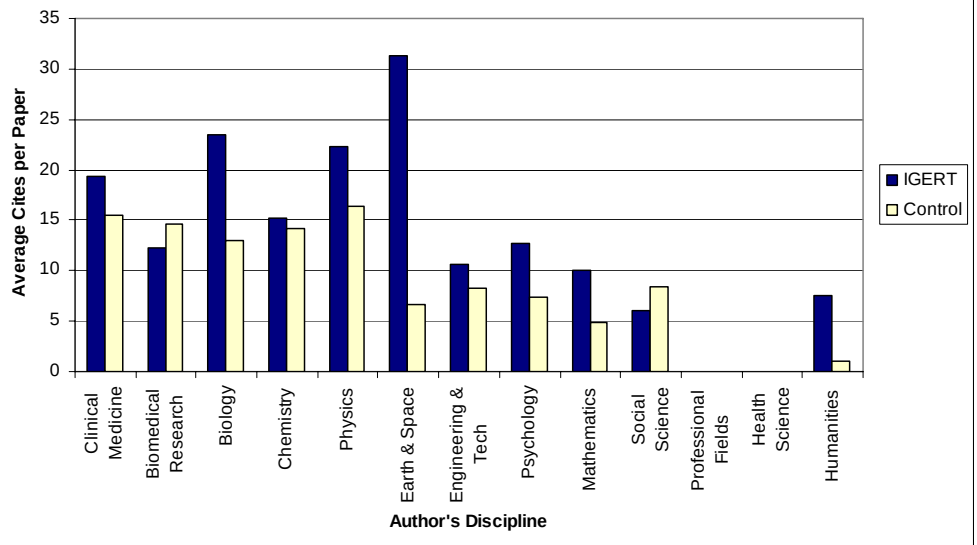
Overall, the IGERT authors receive about 16 citations per paper, while the Control group receives about 12. The trend can be traced over all years of the study, as seen in Figure 7, which illustrates the citation frequency by publication year (see also Table 9). The total number of citations lessens each year only because recent years (2003) do not yet have the time to be cited. But the important point is that in each year, the IGERT authors are more heavily cited. The trend does not appear to be accidental, but points to IGERT's cites per paper being consistently higher than the Control's cites per paper.

Figure 7:
Citation Frequency by Publication Year



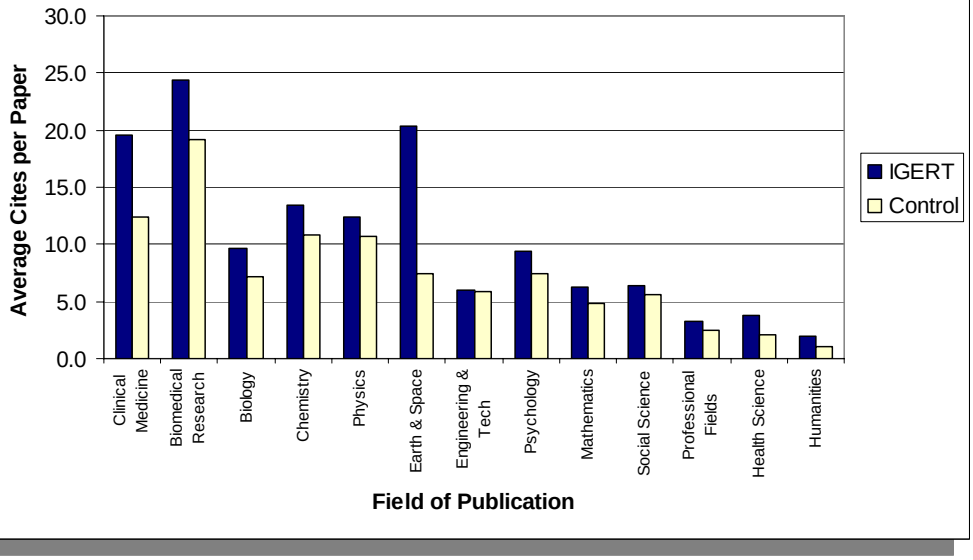
We can see the same trend even if we break the data down by the discipline of the authors, as seen in Figure 8, which presents the citation data by discipline across all years (see also Table 10). Here again, the IGERT authors are more highly cited regardless of their disciplines, except for those authors in Biomedical Research and Social Science, although in both of these cases the citation rates are quite close.

Figure 8:
Citation Frequency by Author's Discipline



Furthermore, the tendency of IGERT authors to be more highly cited is true regardless of which field they publish in. Figure 9 illustrates this point (see also Table 11). The difference between Figures 8 and 9 should be stressed. In the first figure, the data is grouped by the discipline of the author – that is, it compares the Clinical

Figure 9:
Citation Frequency by Field of Publication



Medicine authors in the IGERT group with the Clinical Medicine authors in the control group. In the second figure, the data is grouped by the field of publication, regardless of the author's discipline–that is, it compares the Clinical Medicine papers of all IGERT authors with the Clinical Medicine papers of all control authors.

The difference is most notable in Earth and Space in which the IGERT authors actually receive 20 citations per publication, while the control authors receive only 7. But it is also obvious in Clinical Medicine. The trend becomes less clear-cut in the social sciences, as well as in Engineering and Technology. But the data very clearly points to a real difference between the two groups, and the IGERT authors have a higher impact than others.

COMPARISON OF REFERENCES

References are indicators of an author's research. Looking at references will enable us to make a third attempt to see if the IGERT program has encouraged interdisciplinarity among is participants. We will do this by seeing if IGERT authors are more likely than Control authors to reference work outside their own disciplines.

As a purely preliminary finding, Figure 10 compares the IGERT and Control authors by the number of references per publication (see also Table 12). This comparison is not pertinent to the point of interdisciplinarity, but it is important to note that in sheer numbers, there are no major differences between the two groups, and more importantly, both groups offer sufficient references to make further comparisons meaningful.

Figure 10:
Frequency of Referencing

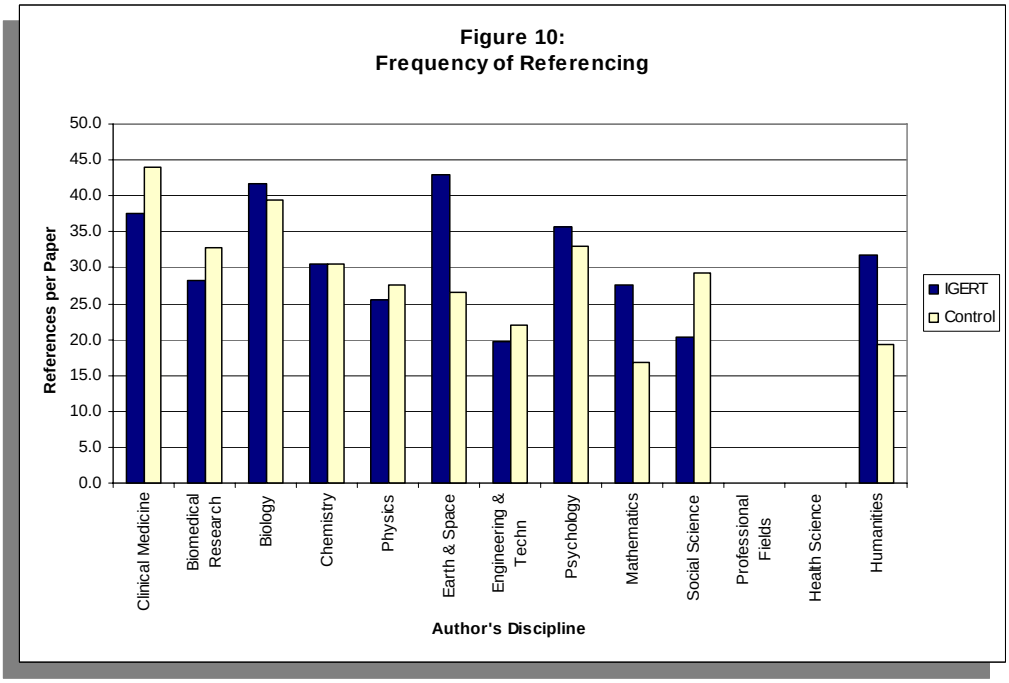
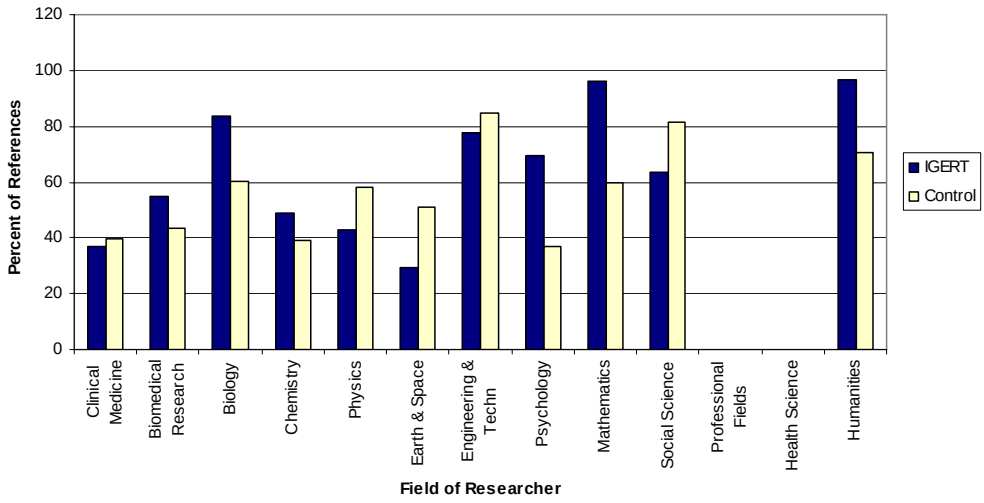


Figure 11 compares the percent of references that are outside the author's discipline (see also Table 13). The results are mixed. Overall 60.2% of all references from IGERT authors, and 54.5% of all references from Control authors, are to fields outside the author's discipline. But in certain fields the IGERT authors are more likely than Control authors to reference papers outside their discipline. This is most striking for the authors in the disciplines of Biology, Psychology, Mathematics, and Humanities, precisely those authors who are most likely to publish outside their fields. But it is true also, although less noteworthy, in Biomedical Research and Chemistry.

Figure 11:
Percent of References to Journals outside the Researcher's Field



CO-AUTHORSHIPS

Co-authorship is a measure of cooperation among authors. It is a useful measure to see if the IGERT program has fostered a degree of diversity among its participants.

In this section, co-authorship refers specifically to *institutional* co-authorship, i.e. the number of institutional addresses listed on each paper. This differs from the more traditional use of co-authorship in that multiple co-authors working at the same institutional address will list that address only once.

Figure 12 illustrates the average number of institutions on a paper for IGERT and Control groups (see also Table 14). The results are, once again, quite mixed. IGERT authors average 1.96 institutions on their papers, while Control authors average 1.78 institutions. In certain disciplines (Clinical Medicine, Biomedical Research, and Engineering and Technology) the papers published by IGERT authors have more institutions than the Control authors; in other disciplines, the opposite is true. In no case is the difference very great.

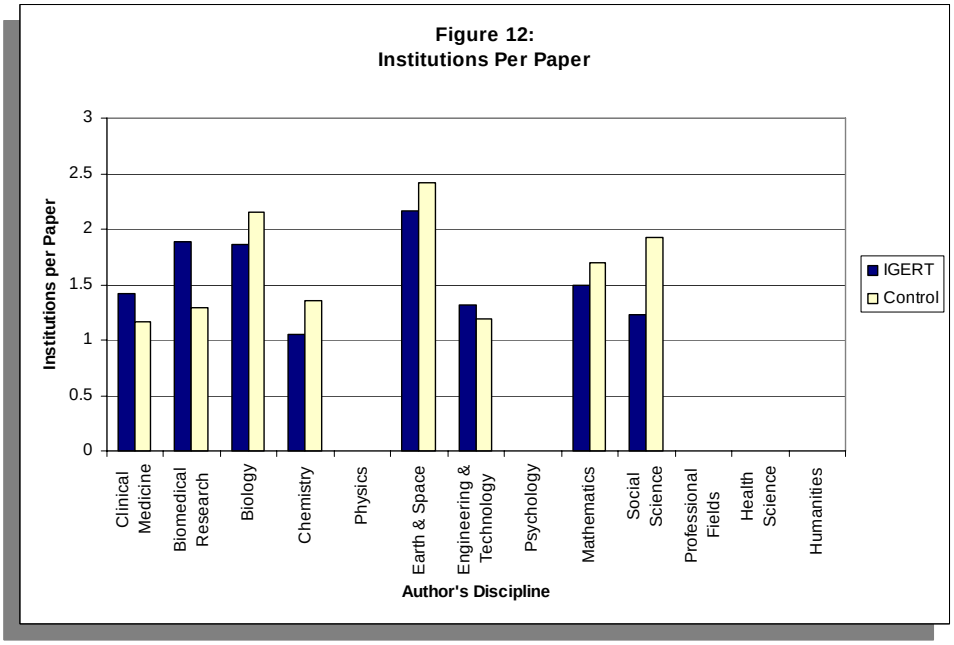
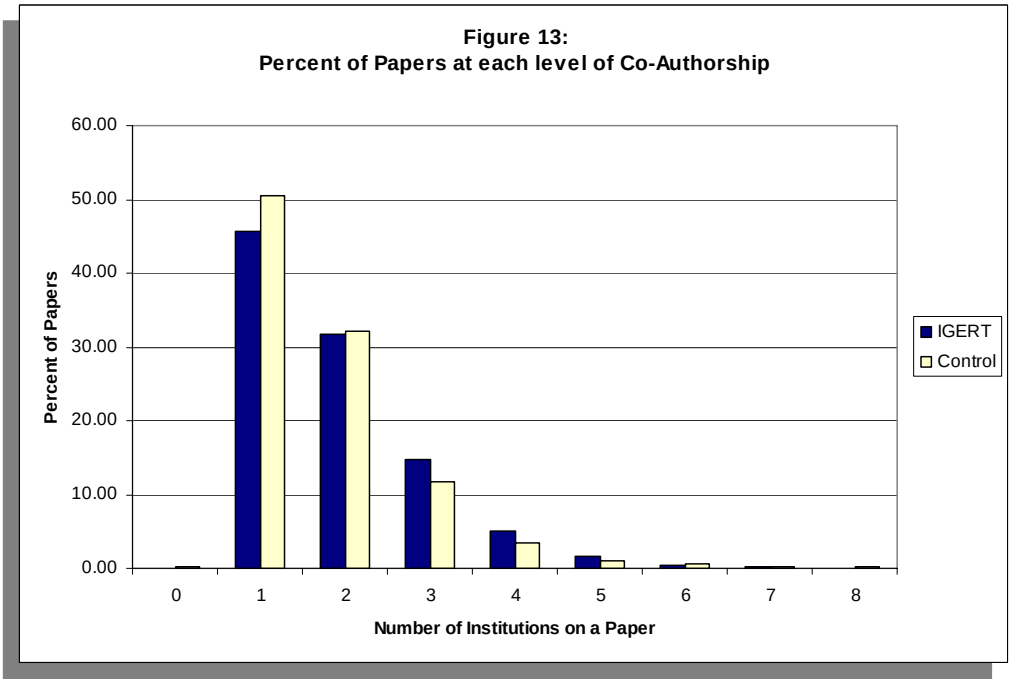
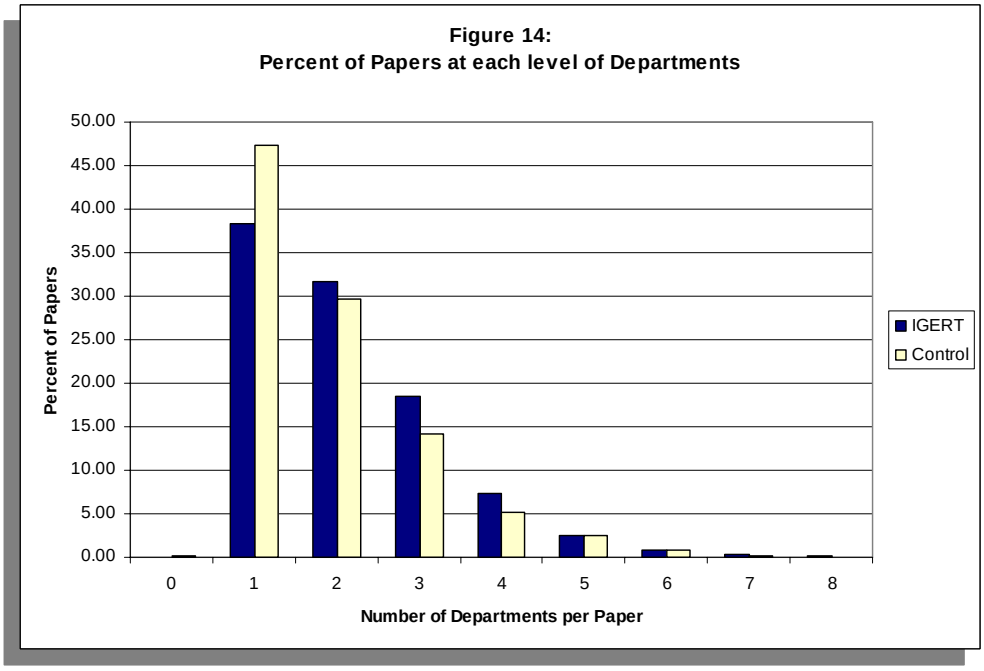


Figure 13 is a slightly different view of the same measure, plotting the percent of papers that have a given number of institutions (see also Table 15). Aside from a very slight tendency for IGERT authors to concentrate at the high levels of co-authorship (for example, papers having 3 or more co-authors), the data does not present a striking difference between the two groups. (A note on Figure 13: there are one IGERT paper, and four Control papers, that have zero institutions. This simply means that an institutional address was not included in the author's paper).



If we move to the department level instead of the Institutional level, we find much the same evidence. Overall, the IGERT authors have 2.1 departments on a paper, while the Control authors have 1.78. Figure 14 plots data that is similar to Figure 13, but counts the number of departments on a paper instead of Institutions (see also Table 16). Once again, there is a slight tendency for the IGERT authors to have a high percentage of it papers with multiple departments, but the trend is not at all striking. (Once again, there are a few papers with no departments).

Figure 14:
Percent of Papers at each level of Departments



Conclusion

We have found that *the Integrative Graduate Education Research and Traineeship Program* has had a mixed result. Participants of this program are not notably more prolific (as measured by their publication rate), but they have a higher impact (as measured by the number of citations from subsequent publications) than non-participants. The results point to a mixed picture about the effects of interdisciplinarity among its participants.

Table 1

Listing of K-Codes
as supplied by the
Institute of Scientific Information

K-Code	Meaning
5	News Item
A (or blank)	Aritcle
B	Book Review
E	Editorial
I	Item about an Individual
L	Letter
M	Meeting Abstract
N	Note
R	Review

Table 2

Listing of
Publication Fields
and Author Disciplines

Field	Title
1	Clinical Medicine
2	Biomedical Research
3	Biology
4	Chemistry
5	Physics
6	Earth and Space
7	Engineering and Technology
8	Psychology
9	Mathematics
10	Social Science
11	Professional Fields
12	Health Science
13	Humanities

Table 3

Number of Authors in each Discipline

Author's Discipline	IGERT	Control
Clinical Medicine	20	11
Biomedical Research	55	49
Biology	31	20
Chemistry	34	29
Physics	20	1
Earth & Space Science	16	17
Engineering & Technology	107	81
Psychology	17	4
Mathematics	13	10
Social Science	24	23
Professional Fields	0	0
Health Science	0	0
Humanities	7	4
All Disciplines Combined	344	249

Table 4

Number of Publications by Publication Year
(Across all Disciplines)

	Publication Year					
	1999	2000	2001	2002	2003	1999-2003
IGERT	621	661	605	545	494	2926
Control	458	452	415	414	482	2221

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Table 5

Number of Publications by Author's Discipline

(Papers per Author is found by dividing the number of papers by No. of Authors)

Data for IGERT Authors	No. of	No. with	Publication Years					
Author's Discipline	Authors	Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	20	19	56	54	45	54	55	264
Biomedical Research	55	49	109	111	113	116	104	553
Biology	31	29	69	77	65	66	53	330
Chemistry	34	29	86	85	85	75	64	395
Physics	20	19	59	43	55	50	42	249
Earth & Space	16	12	21	36	27	10	18	112
Engineering & Tech	107	84	182	193	164	122	118	779
Psychology	17	15	18	35	27	31	24	135
Mathematics	13	9	9	13	12	6	5	45
Social Science	24	14	10	9	9	7	8	43
Professional Fields	0	0	0	0	0	0	0	0
Health Science	0	0	0	0	0	0	0	0
Humanities	7	5	2	5	3	8	3	21
All Fields Combined	344	284	621	661	605	545	494	2926

Data for Control Authors	No. of	No. with	Publication Years					
Author's Discipline	Authors	Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	11	11	36	33	37	32	24	162
Biomedical Research	49	48	78	91	77	94	128	468
Biology	20	19	52	43	38	31	34	198
Chemistry	29	29	95	95	73	97	93	453
Physics	1	1	2	2	0	0	2	6
Earth & Space	17	15	35	26	28	23	34	146
Engineering & Tech	81	64	129	122	127	104	115	597
Psychology	4	4	3	9	10	7	15	44
Mathematics	10	8	6	14	9	7	18	54
Social Science	23	15	21	17	16	18	18	90
Professional Fields	0	0	0	0	0	0	0	0
Health Science	0	0	0	0	0	0	0	0
Humanities	4	2	1	0	0	1	1	3
All Fields Combined	249	216	**458**	**452**	**415**	**414**	**482**	**2221**

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Table 6

Number of Publications by Author's Discipline and Publication Field

Data for IGERT Authors

	Researcher Discipline										
Publication Field	**Clinical Medicine**	**Biomedical Research**	**Biology**	**Chemistry**	**Physics**	**Earth & Space Science**	**Engineering & Technology**	**Psychology**	**Mathematics**	**Social Science**	**Professional Fields**
Clinical Medicine	189	128	120	21	17	0	44	69	7	0	0
Biomedical Research	47	221	96	54	49	19	72	10	10	3	0
Biology	4	13	60	3	0	1	12	0	2	6	0
Chemistry	0	64	0	261	2	2	126	0	0	0	0
Physics	5	54	8	45	166	5	144	4	13	0	0
Earth & Space Science	0	17	14	6	0	85	46	0	0	3	0
Engineering & Technology	5	41	22	5	15	0	307	7	7	1	0
Psychology	14	0	7	0	0	0	1	37	0	0	0
Mathematics	0	1	0	0	0	0	13	1	6	1	0
Social Science	0	0	3	0	0	0	2	0	0	25	0
Professional Fields	0	0	0	0	0	0	11	0	0	0	0
Health Science	0	14	0	0	0	0	0	6	0	3	0
Humanities	0	0	0	0	0	0	1	1	0	1	0
All Disciplines Combined	264	553	330	395	249	112	779	135	45	43	0

Data for Control Authors

	Researcher Discipline										
Publication Field	**Clinical Medicine**	**Biomedical Research**	**Biology**	**Chemistry**	**Physics**	**Earth & Space Science**	**Engineering & Technology**	**Psychology**	**Mathematics**	**Social Science**	**Professional Fields**
Clinical Medicine	125	166	11	2	0	1	10	7	0	2	0
Biomedical Research	30	230	87	37	1	5	52	3	1	21	0
Biology	1	7	86	2	0	0	7	0	0	16	0
Chemistry	0	26	0	314	4	2	190	1	0	0	0
Physics	1	12	1	80	1	42	77	1	20	3	0
Earth & Space Science	0	0	5	1	0	91	82	0	0	3	0
Engineering & Technology	1	19	1	15	0	4	158	0	8	0	0
Psychology	4	5	5	0	0	0	1	31	0	3	0
Mathematics	0	0	1	2	0	0	9	0	25	0	0
Social Science	0	0	1	0	0	1	7	0	0	37	0
Professional Fields	0	0	0	0	0	0	4	0	0	1	0
Health Science	0	3	0	0	0	0	0	1	0	4	0
Humanities	0	0	0	0	0	0	0	0	0	0	0
All Disciplines Combined	162	468	198	453	6	146	597	44	54	90	0

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Table 7
Number of Publications by Discipline Type *

Data for IGERT Authors

	Publication Year					
Discipline Type	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Single Field Authors	13	14	14	20	9	70
Multiple Subfield Authors	63	48	40	33	34	218
Multiple Field Authors	512	562	534	471	428	2507
Outside Field Authors	33	37	17	21	23	131
Total	621	661	605	545	494	2926

Data for Control Authors

	Publication Year					
Discipline Type	**1999**	**2000**	**2001**	**2002**	**2003**	**1999-2003**
Single Field Authors	17	15	16	11	17	76
Multiple Subfield Authors	29	38	28	46	37	178
Multiple Field Authors	383	376	357	342	410	1868
Outside Field Authors	29	23	14	15	18	99
Total	458	452	415	414	482	2221

* Definition of Discipline Types

Single Field Authors	Researcher publishes only within own field, and only within one subfield
Multiple Subfield Authors	Researcher publishes only within own field, but in multiple subfields
Multiple Field Authors	Researcher publishes within own field AND in other fields
Outside Field Authors	Researcher publishes only outside own field

Table 8
Number of Researchers by Publication Spread

Data for IGERT Authors		Data for Control Authors	
Number of fields including own	**Number of researchers**	**Number of fields including own**	**Number of researchers**
2	79	2	45
3	62	3	55
4	34	4	26
5	15	5	9
6	7	6	5
7	1	7	0
8	1	8	0
9	1	9	0
2 or more	200	2 or more	140
Ave # flds per researcher	3.105	Ave # flds per researcher	3.1

Table 9
Number of Citations by Publication Year

	IGERT Authors		Control Authors	
Publication Year	**Citations**	**Publications**	**Citations**	**Publications**
1999	14823	621	9211	458
2000	14013	661	6265	452
2001	8722	605	5366	415
2002	5786	545	3132	414
2003	2244	494	1642	482
1999-2003	45588	2926	25616	2221

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Table 10

Number of Citations by Author's Discipline

Citations per Paper is found by dividing the number of Citations by No. of Pubs)

Data for IGERT Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	20	19	**264**	1712	1758	908	486	233	5097
Biomedical Research	55	49	**553**	2311	1445	1487	1150	426	6819
Biology	31	29	**330**	2461	2543	1436	1061	256	7757
Chemistry	34	29	**395**	1893	1791	1237	847	263	6031
Physics	20	19	**249**	1780	1873	1129	441	335	5558
Earth & Space	16	12	**112**	659	1394	573	649	229	3504
Engineering & Tech	107	84	**779**	2945	2636	1490	801	372	8244
Psychology	17	15	**135**	696	364	362	181	105	1708
Mathematics	13	9	**45**	264	62	53	63	11	453
Social Science	24	14	**43**	79	84	39	49	9	260
Professional Fields	0	0	**0**	0	0	0	0	0	0
Health Science	0	0	**0**	0	0	0	0	0	0
Humanities	7	5	**21**	23	63	8	58	5	157
All Fields Combined	344	284	**2926**	14823	14013	8722	5786	2244	45588

Data for Control Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	11	11	**162**	786	578	618	421	104	2507
Biomedical Research	49	48	**468**	1828	1886	1868	825	435	6842
Biology	20	19	**198**	1126	615	472	240	112	2565
Chemistry	29	29	**453**	2630	1329	1072	852	513	6396
Physics	1	1	**6**	74	22	0	0	2	98
Earth & Space	17	15	**146**	382	173	247	90	77	969
Engineering & Tech	81	64	**597**	1864	1339	832	542	318	4895
Psychology	4	4	**44**	122	71	53	50	30	326
Mathematics	10	8	**54**	57	109	47	24	27	264
Social Science	23	15	**90**	342	143	157	87	22	751
Professional Fields	0	0	**0**	0	0	0	0	0	0
Health Science	0	0	**0**	0	0	0	0	0	0
Humanities	4	2	**3**	0	0	0	1	2	3
All Fields Combined	249	216	**2221**	9211	6265	5366	3132	1642	25616

Table 11

Number of Citations by Publication Field

(Citations per Paper is found by dividing the number of Citations by No. of Pubs)

Data for IGERT Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	20	19	**264**	4040	3555	2344	1364	426	11729
Biomedical Research	55	49	**553**	4664	4399	2505	1824	811	14203
Biology	31	29	**330**	341	125	284	148	77	975
Chemistry	34	29	**395**	1885	1725	1390	754	333	6087
Physics	20	19	**249**	1991	1726	953	647	205	5522
Earth & Space	16	12	**112**	670	1471	464	678	202	3485
Engineering & Tech	107	84	**779**	940	629	531	178	162	2440
Psychology	17	15	**135**	194	268	100	110	14	686
Mathematics	13	9	**45**	13	14	86	18	7	138
Social Science	24	14	**43**	71	50	23	46	0	190
Professional Fields	0	0	**0**	5	2	24	5	0	36
Health Science	0	0	**0**	7	49	16	8	7	87
Humanities	7	5	**21**	2	0	2	6	0	10
All Fields Combined	344	284	**2926**	14823	14013	8722	5786	2244	45588

Data for Control Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	11	11	**162**	1487	841	893	506	298	4025
Biomedical Research	49	48	**468**	3079	2222	1976	1222	485	8984
Biology	20	19	**198**	278	262	216	59	46	861
Chemistry	29	29	**453**	2124	1260	1242	781	372	5779
Physics	1	1	**6**	918	739	426	228	245	2556
Earth & Space	17	15	**146**	582	345	227	118	81	1353
Engineering & Tech	81	64	**597**	393	382	224	139	77	1215
Psychology	4	4	**44**	148	71	87	47	18	371
Mathematics	10	8	**54**	48	73	43	6	8	178
Social Science	23	15	**90**	143	70	22	18	8	261
Professional Fields	0	0	**0**	0	0	10	1	4	15
Health Science	0	0	**0**	11	0	0	6	0	17
Humanities	4	2	**3**	0	0	0	1	0	1
All Fields Combined	249	216	**2221**	9211	6265	5366	3132	1642	25616

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Table 12

Number of References by Author's Discipline

(References per Paper is found by dividing the number of References by No. of Pubs)

Data for IGERT Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	20	19	**264**	1934	2092	2198	1826	1874	9924
Biomedical Research	55	49	**553**	2929	3126	2993	3195	3364	15607
Biology	31	29	**330**	2646	3019	3028	2839	2201	13733
Chemistry	34	29	**395**	2483	2421	2505	2483	2135	12027
Physics	20	19	**249**	1321	1228	1750	986	1061	6346
Earth & Space	16	12	**112**	650	1168	873	1111	1003	4805
Engineering & Tech	107	84	**779**	3246	3771	3273	2780	2280	15350
Psychology	17	15	**135**	596	1180	981	1124	950	4831
Mathematics	13	9	**45**	269	195	324	236	214	1238
Social Science	24	14	**43**	174	138	250	163	150	875
Professional Fields	0	0	**0**	0	0	0	0	0	0
Health Science	0	0	**0**	0	0	0	0	0	0
Humanities	7	5	**21**	60	192	36	274	106	668
All Fields Combined	344	284	**2926**	16308	18530	18211	17017	15338	85404

Data for Control Authors

				Publication Year					
	No. of Authors	No with Pubs	No. of Pubs	1999	2000	2001	2002	2003	1999-2003
Clinical Medicine	11	11	**162**	1400	1398	1807	1324	1207	7136
Biomedical Research	49	48	**468**	2680	2790	2599	2940	4327	15336
Biology	20	19	**198**	1852	1562	1671	1369	1367	7821
Chemistry	29	29	**453**	2997	2578	2427	3128	2706	13836
Physics	1	1	**6**	105	28	0	0	32	165
Earth & Space	17	15	**146**	745	678	791	730	945	3889
Engineering & Tech	81	64	**597**	2894	2718	2466	2377	2678	13133
Psychology	4	4	**44**	82	219	352	201	598	1452
Mathematics	10	8	**54**	95	174	111	134	389	903
Social Science	23	15	**90**	632	310	515	684	497	2638
Professional Fields	0	0	**0**	0	0	0	0	0	0
Health Science	0	0	**0**	0	0	0	0	0	0
Humanities	4	2	**3**	5	0	0	23	30	58
All Fields Combined	249	216	**2221**	13487	12455	12739	12910	14776	66367

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Table 13

Number of References by Author's Discipline and Publication Field

Data for IGERT Authors

	Researcher Discipline										
	Clinical Medicine	Biomedical Research	Biology	Chemistry	Physics	Earth & Space Science	Engineering & Technology	Psychology	Mathematics	Social Science	Professional Fields
Clinical Medicine	6276	4312	4525	657	651	1	1248	2374	383	42	0
Biomedical Research	2662	7041	5989	2433	1519	967	2187	655	460	141	0
Biology	44	277	2242	75	15	88	198	11	42	170	0
Chemistry	26	1609	28	6129	294	74	3131	0	11	0	0
Physics	128	940	183	2311	3625	199	3707	62	191	3	0
Earth & Space	2	571	234	139	22	3409	826	1	0	84	0
Engineering & Tech	25	480	164	216	184	46	3444	61	83	8	0
Psychology	663	142	223	0	4	0	54	1465	11	41	0
Mathematics	12	50	26	26	22	11	232	13	50	25	0
Social Science	0	3	71	2	0	1	67	10	0	319	0
Professional Fields	14	2	2	1	0	0	131	3	0	6	0
Health Science	38	83	7	0	1	0	12	134	0	16	0
Humanities	0	0	2	1	0	0	2	19	0	7	0
Unknown	34	97	37	37	9	9	111	23	7	13	0
All Fields Combined	9924	15607	13733	12027	6346	4805	15350	4831	1238	875	0

Data for Control Authors

	Researcher Discipline										
	Clinical Medicine	Biomedical Research	Biology	Chemistry	Physics	Earth & Space Science	Engineering & Technology	Psychology	Mathematics	Social Science	Professional Fields
Clinical Medicine	4290	4756	402	57	0	23	372	323	6	170	0
Biomedical Research	2384	8648	3734	1744	40	329	1626	80	8	855	0
Biology	45	139	3125	87	0	138	265	29	3	633	0
Chemistry	21	697	41	8406	53	314	3925	1	0	5	0
Physics	133	489	31	3015	69	1038	2569	5	410	73	0
Earth & Space	1	17	204	43	0	1902	1875	0	8	73	0
Engineering & Tech	2	242	15	428	2	101	1979	0	96	29	0
Psychology	216	200	152	1	0	0	11	918	0	117	0
Mathematics	0	18	12	23	1	12	173	3	364	19	0
Social Science	7	4	31	0	0	4	79	44	3	493	0
Professional Fields	1	0	1	1	0	0	137	20	3	48	0
Health Science	10	15	0	0	0	1	5	15	0	97	0
Humanities	1	0	2	0	0	0	0	1	0	7	0
Unknown	25	111	71	31	0	27	117	13	2	19	0
All Fields Combined	7136	15336	7821	13836	165	3889	13133	1452	903	2638	0

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Table 14

Number of Institutions on a Publication by Author's Discipline

	IGERT Authors	Control Authors
Clinical Medicine	1.42	1.16
Biomedical Research	1.89	1.29
Biology	1.86	2.15
Chemistry	1.05	1.35
Physics	*	*
Earth & Space	2.16	2.42
Engineering & Tech	1.32	1.19
Psychology	*	*
Mathematics	1.49	1.7
Social Science	1.23	1.92
Professional Fields	*	*
Health Science	*	*
Humanities	*	*

* Too few researchers to effect a meaningful comparison

Table 15
Number of Institutions on a Publication

IGERT Authors		Control Authors	
No. of Departments	Pubs with this No. of Departments	No. of Departments	Pubs with this No. of Departments
0	1	0	4
1	1333	1	1122
2	926	2	714
3	433	3	258
4	150	4	76
5	47	5	23
6	14	6	12
7	4	7	3
8	2	8	5
Total	2910	Total	2217

Table 16
Number of Departments on a Publication

IGERT Authors		Control Authors	
No. of Departments	Pubs with this No. of Departments	No. of Departments	Pubs with this No. of Departments
0	1	0	4
1	1121	1	1053
2	927	2	658
3	543	3	313
4	215	4	115
5	75	5	55
6	24	6	17
7	11	7	5
8	4	8	0
Total	2926	Total	2221

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