IGERT Implementation and Early Outcomes

Final Report

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Executive Summary

Responding to changes in the demands on the country's science and engineering research community since the end of the Cold War, the National Science Foundation (NSF) introduced the Integrative Graduate Education and Research Traineeship (IGERT) program in 1997 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. The IGERT program encourages innovation in graduate education by supporting the development of broad-based graduate education centered on an inter/multidisciplinary research theme. In addition to the traditional emphasis on excellent research skills, IGERT trainees are also expected to master communication and teamwork. It is expected that IGERT projects will broaden trainees' career horizons by exposing them to a variety of work environments, and increase trainees' understanding of and comfort level with individuals from other backgrounds and/or countries by allowing trainees to serve as members of collaborative partnerships and diverse research teams. In addition, IGERT strongly emphasizes the inclusion of groups underrepresented in science and engineering, to take advantage of all of our nation's human resources.

With the IGERT program now at the close of its second year of funding, NSF asked Abt Associates to assess the program's implementation and early outcomes through an analysis of data from NSF's web survey of all IGERT Principal Investigators (PIs) and students (all funded trainees and some non-funded student associates). PIs were asked questions about process (e.g., implementation challenges, recruitment of trainees) as well as progress towards IGERT goals for trainees (e.g., research skills, skills applicable to careers in industry, communication skills, international perspective). Trainees were asked about their IGERT experiences and how effective their education has been.

Implementation

It would appear that implementation of these first two cohorts of IGERT projects is proceeding reasonably well. The chief implementation barriers reported thus far are largely those associated with the shift from traditional departmental culture to an inter/multidisciplinary program. Regardless of the evident difficulty of this shift in culture, it should be noted that the majority of the highlights cited by PIs also center on the inter/multidisciplinary nature of their projects and the new opportunities and research advances this new synergy of disciplines allowed and encouraged.

IGERT projects have made little progress in modifying the demographic make-up of the graduate population. Although NSF encourages IGERT institutions to recruit students from populations traditionally underrepresented in science and engineering (i.e., women, specified racial/ethnic minorities, and persons with disabilities), the trainee populations do not appear thus far to have higher rates of inclusion of these populations than national norms for science and engineering graduate programs.

Early Outcomes

All of the projects with trainees during the reporting period (33 of the 38 awardee projects) have made progress towards the various program objectives. Topping the list of effective activities were inter/multidisciplinary trainee activities, from communication with individuals in other fields to

participation in inter/multidisciplinary research endeavors. Also successful have been activities aimed at preparing students for careers outside of the academic world. Areas of progress across the projects included:

- **Inter/multidisciplinary research and education:** All of the projects have successfully begun to create an inter/multidisciplinary education environment. All of the projects report having centered their program around an inter/multidisciplinary theme and most also report funding trainees from a variety of fields, requiring trainees to take courses outside their primary area of study, and creating research projects in which trainees work with faculty from a variety of disciplinary fields. Most trainees, in turn, report taking classes outside their primary discipline and experiencing a variety of inter/multidisciplinary activities.

- **Communication and teamwork skills:** Both PIs and trainees report that IGERT trainees are gaining communication and teamwork skills, most frequently at this early stage of their graduate education through in-house experience with communication across disciplinary boundaries, oral presentations, and team educational or research ventures. Over half of these activities were developed specifically for the IGERT program.

- **Preparation to conduct high-quality research:** Almost all of the PIs report educating their students in research methods and state-of-the-art instrumentation with an inter/ multidisciplinary twist. Trainees mirror this, reporting, for example, that they learn research methods and ethics through working on inter/multidisciplinary projects with professors and graduate students outside their own field. The IGERT projects appear to have combined a mix of existing research activities with new developments instituted for the IGERT program.

- **Preparation for faculty positions:** Given the IGERT program's focus on preparation of students for non-academic careers, most projects have not concentrated their efforts on traditional academic preparation as much as they have on other areas. Trainees do receive some preparation for faculty positions, most notably through positions as teaching assistants. Of all the areas of development, preparation for faculty positions appears to have incorporated more pre-existing institutional activities than the other areas.

- **Preparation for careers in industry or the public sector:** Most PIs report that IGERT projects are succeeding in providing trainees with the skills needed to pursue a career in industry or the public sector. Two-thirds of the projects have already set up internships or other interactions with outside agencies through which trainees can gain exposure to alternate career paths. Trainees report experiences in research laboratories at other institutions, outside companies, and government agencies. Three-quarters or more of the activities developed to prepare trainees for non-academic careers were developed specifically for the IGERT program.

- **Expansion of trainees' international perspectives:** Trainees most frequently gain exposure to individuals from other backgrounds or cultures at their home institutions by interacting with visiting scholars or international students. A small number of projects, however, have instituted partnerships with international sites at which their trainees can experience research practices in other countries. Trainees reported that improved

communication skills was the greatest benefit of working with individuals from different backgrounds.

After one or two years of funding, the IGERT projects show strong promise of fulfilling NSF's program goals. It remains to site visits and continued project monitoring through the web survey to determine more fully the program's effects and success.

Section 1: Program Characteristics

Introduction and Context

To meet the challenges of ensuring that Ph.D. scientists and engineers have the inter/multidisciplinary backgrounds and the technical, professional, and personal skills needed for the career demands of the future, the National Science Foundation (NSF) initiated the Integrative Graduate Education and Research Traineeship (IGERT) Program in 1997.[1] The program is intended to catalyze a cultural change in graduate education by establishing new, innovative models for graduate education which transcend traditional disciplinary and institutional boundaries.[2] The IGERT program seeks to structure graduate education around inter/multidisciplinary research themes and provide students with professional growth experiences in various career environments. The program encourages the development of a range of personal skills in students, including teamwork and communication (oral and written, across disciplinary, sectoral and national boundaries).

An IGERT project brings together investigators from one or more departments within a single institution, or from more than one institution, in a spirit of collaboration. The emphasis of the IGERT program is on the education of graduate students; however, the program also supports efforts that include undergraduate and/or postdoctoral students if such participation strengthens the proposed graduate education program. Each IGERT project receives a grant award of up to $500,000 per year for five years, most of which is spent on graduate student tuition and stipend support, with the option of an additional $200,000 in the first year for special equipment or software purchases.

In 1998 and 1999, a total of 38 IGERT projects were funded. Information on these first two years of operation has been collected through a web-based Data Reporting System from project Principal Investigators (PIs), funded graduate student trainees, and non-funded associates (graduate students participating in the IGERT doctoral program but not receiving IGERT funds). The survey covers a number of topics. Respondents answer a series of closed-ended questions in each section and then have the opportunity to elaborate on, explain, or provide examples for their responses in an open-ended textbox. The report presents findings from this survey for the first two years of IGERT funding, beginning with descriptions of the project participants and then exploring early project outcomes for each of the program's goals. Barriers to implementation and program highlights as revealed by PI comments are discussed, as well as the impacts projects have had on their home institutions. Appendix A contains a list of the inter/multidisciplinary themes of the projects. Information about consortial arrangements and additional funding sources can be found at the end of the report in Appendices B and C. Appendix D contains a sample copy of the survey instrument as it appeared on the web.

The IGERT Projects

Through 1999, NSF funded 38 IGERT projects, 17 of which began in 1998 and 21 in 1999. In keeping with the inter/multidisciplinary focus of the IGERT program, the projects span all of NSF's areas: Biology; Computer and Information Sciences; Education and Human Resources; Engineering;

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[1]   NSF Press Release #00-52, August 2000.

[2]   IGERT webpage: www.nsf.gov/home/crssprgm/igert/igertabs.htm; viewed 9/29/00.

Geosciences; Math and Physical Sciences; Social, Behavioral and Economic Sciences; and the Office of Polar Programs. A listing of each project's inter/multidisciplinary research theme is presented in Appendix A. Because of the strong inter/multidisciplinary character of these projects, we will not attempt to identify them with any one directorate.

Exhibit 1.1 presents descriptive information about these projects and their students (trainees and associates). There are five sites (one 1998 project and four 1999 projects) that had not yet begun to fund trainees at the time of data collection, all of which report they have since funded trainees (who enrolled for the 2000-2001 academic year). As might be expected, the 1998 projects have, on average, more trainees per project than the 1999 projects (11.8 as compared to 6.8). Geographically the sites span half of the states in the United States, as displayed in Exhibit 1.2, with just less than a quarter of those states having more than one site.

Exhibit 1.1: Projects, Trainees, and Associates by Cohort

	1998 Cohort	1999 Cohort	All projects
Number of Projects	17	21	38
Number of Projects Reporting Trainees	16	17	33
Number of Funded Trainees	189	116	305
Number of Projects Reporting (Non-Funded) Associates	9	12	21
Number of (Non-Funded) Associates	72	80	152
Average Number of Trainees per Project	11.8	6.8	9.2
Average Number of Associates per Project	8.0	6.7	7.2

Exhibit 1.2: Geographic Distribution of IGERT Program Sites

Any state containing an IGERT program site is shaded. If a state contains more than one site, the number of sites is indicated with a numeral.
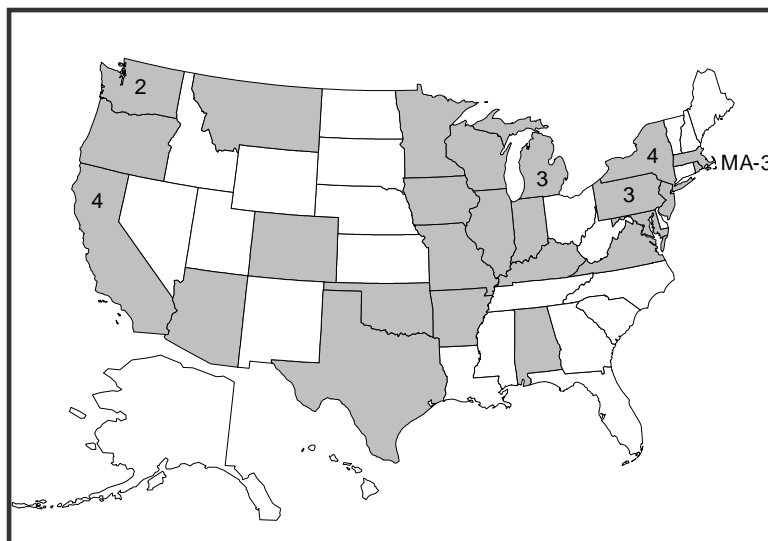
Principal Investigators

One goal of the IGERT program is to increase the numbers of underrepresented groups in science and engineering programs. Evidence of the need for more inclusion is found when examining the PIs, who taken collectively are not overly diverse. Twenty-four percent of all IGERT PIs are women. Only two (five percent) report themselves as underrepresented minorities, and none report having a disability.[3] Across all 38 projects there are 468 Co-Principal Investigators (Co-PIs) and/or faculty identified as advisors of trainees or associates, of whom only 16 percent are women, 6 percent are from underrepresented ethnic groups, and 1 percent are disabled.

Trainees and Associates

Although small allowances are made for indirect and equipment expenditures, the bulk of each IGERT grant is earmarked for trainee stipends and tuition support. With these funds the IGERT program currently supports 305 trainees at 33 sites. In addition to the funded trainees, many projects enroll other graduate students who experience the same curriculum and activities as trainees but do not receive IGERT funding. Some PIs expressed an interest in being able to include these students in their survey responses, in order to allow a more complete representation of the student population. In such cases, non-funded students completed the same survey as the trainees and have been counted as associates in our descriptions of the student population, although not in other sections of the report. It should be noted that a project's lack of reported associates does not mean that no graduate students outside of trainees are taking part in that project's IGERT activities, only that no such students completed the survey.

Ninety-nine percent of all trainees are reported to be United States citizens or permanent residents,[4] which stands in stark contrast to the associates of the projects, 66 percent of whom are *not* United States citizens. The multicultural and international nature of non-trainee graduate students enrolled in IGERT departments (represented in our data set by the associates) is frequently mentioned by IGERT trainees when discussing their classmates and the benefits of working with individuals from other countries.

One of NSF's primary goals for the IGERT program is increasing student diversity in science and engineering doctoral programs along such dimensions as gender, race/ethnicity,[5] and disability status. But while diversity is a stated program goal of IGERT, the percentages of IGERT trainees who are of underrepresented minority status does not differ from national norms (10 percent underrepresented minorities). Moreover, females are less well represented in the current IGERT projects (24 percent)

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[3] Disability status options include: hearing, visual, mobility/orthopedic impairments, or self-defined "other."

[4] Three non-US citizen/permanent residents are listed as IGERT trainees. Two of these pose no funding violation: one was dropped from funding when the project understood that NSF supports only U.S. citizens, and the other was funded with matching funds from the participating school of engineering (and should be listed as an IGERT associate, not a trainee). The third is a Canadian citizen about whom we were unable to obtain further information.

[5] Specifically those minority groups identified by NSF as underrepresented in science and engineering: Blacks, Hispanics, American Indians, and Alaskan Natives.

than in graduate enrollment in science and engineering overall (38 percent).[6] Involvement of underrepresented minorities and females is slightly less for associates than for trainees (9 percent and 23 percent, respectively).

PI Assessment of Trainee Quality

PIs were asked to rate their trainees in comparison to other graduate students. Overall, they felt the IGERT trainees had more promise than their usual graduate students. Of the 33 PIs at sites with trainees, 6 (18 percent) rated their trainees as "far superior to our usual graduate students," while 23 (80 percent) gave trainees a rating of "somewhat better than our usual students." Only three PIs (nine percent) said that their trainees were equivalent to their normal students ("about the same"), and no PIs rated their trainees as being "somewhat" or "much" less promising or less successful than their usual students.

Student Background

Given the IGERT program's emphasis on inter/multidisciplinary education, it is not surprising that IGERT trainees come from a variety of academic and professional backgrounds. Trainees at the average IGERT project come from 5.4 different undergraduate majors (with one site containing trainees with 13 different undergraduate degree fields). They earned their bachelor degrees sometime between 1971 and 2000, although 88 percent graduated in the last 10 years. One third of all IGERT trainees entered the program having earned a previous post graduate degree, primarily master's degrees but also including two prior doctorate degrees and a smattering of other degrees (for example, one professional degree).

IGERT trainees also had considerable work experience prior to enrolling in the IGERT doctoral programs. Almost half of all trainees (46 percent) were employed in the public or private sector for one or more years after receiving their first undergraduate degree and prior to becoming an IGERT trainee. Of these individuals, over half worked only for one or two years, while one in five (19 percent) worked for over five years.

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[6]   Science and Engineering Indicators 1998, NSB-98-1, Appendix Tables 2-24 and 2-25, Graduate Enrollment in Science and Engineering

Section 2: Creating and Sustaining the Trainee Population

Recruitment

Contributing to a diverse science and engineering workforce is a primary goal of the IGERT program. Thus, in addition to seeking highly qualified applicants from the fields making up their inter/multidisciplinary research area, NSF encourages IGERT institutions to recruit students from populations traditionally underrepresented in science and engineering (i.e., women, specified racial/ethnic minorities, and persons with disabilities). To do this, projects utilized a variety of recruitment strategies, which are presented in Exhibit 2.1 in order of their frequency of use.

The three most popular recruitment strategies, reported by more than 90 percent of the PIs, were: offering competitive stipends and other support; distributing brochures, posters, or other non-electronic media describing the availability of NSF-IGERT funds; and using faculty members' personal contacts to identify and attract prospective trainees. Projects also communicated with prospective trainees nationally by placing advertisements in scholarly journals and by attending graduate student associations' meetings and fairs.

Almost all of the PIs mentioned additional recruitment strategies in their textbox comments or highlighted those they found most successful. The most popular of these was the creation of a program-specific web-page. Other strategies included: contacting interested students by phone or electronic mail; providing funds to current IGERT trainees to travel to conferences or their alma maters to publicize the program; recruiting at national professional organizations' meetings and through industrial contacts; and advertising by electronic mail on selected list serves.

Recruitment patterns of the 1998 and 1999 cohort institutions were very similar. The primary difference lay in the 1999 cohort's greater likelihood (76 percent versus 53 percent) to offer a "Research Experiences for Undergraduates" (REU) program. REU is a NSF-funded program which provides opportunities for undergraduate students to experience hands-on participation in research and related scholarly activities. (REU is discussed in greater detail in Section 3 of this report.)

The left-most column of Exhibit 2.1 indicates with a '✓' those strategies which are frequently used to target either minority or female students. Note that three of the top four recruitment strategies frequently used to recruit underrepresented groups are not aimed solely at those populations.

Exhibit 2.1: Recruitment Strategies Used by IGERT Projects

(Presented in descending frequency of use.)

Particularly important in recruiting underrepresented groups (indicated with a ✓)	Percent (n) 1998 n=17	1999 n=21	All n=38
Strategy			
Offer competitive stipends and other support	**100%** (17)	**95%** (20)	**97%** (37)
Distribute non-electronic media citing IGERT funds	**100%** (17)	**90%** (19)	**95%** (36)
Use faculty personal contacts to identify and attract prospective trainees	**94%** (16)	**90%** (19)	**92%** (35)
National meetings/graduate student fairs	**88%** (15)	**90%** (19)	**89%** (34)
✓ Recruit undergraduates already enrolled at IGERT campus	**94%** (16)	**81%** (17)	**87%** (33)
Invite prospective trainees to campus	**88%** (15)	**81%** (17)	**84%** (32)
Place advertisements in scholarly journals or electronic media citing IGERT funds	**76%** (13)	**86%** (18)	**82%** (31)
✓ Ensure that entry requirements do not unnecessarily exclude prospective students	**76%** (13)	**71%** (15)	**74%** (28)
✓ Recruit through minority science organizations	**65%** (11)	**71%** (15)	**68%** (26)
✓ Offer research experiences for undergraduates (REU) at IGERT institution	**53%** (9)	**76%** (16)	**66%** (25)
Informational visits to undergraduate institutions	**53%** (9)	**43%** (9)	**47%** (18)
✓ Recruit through women's science organizations	**53%** (9)	**38%** (8)	**45%** (17)
✓ Recruit through national institutional initiatives (e.g. AMP)	**47%** (8)	**29%** (6)	**37%** (14)
✓ Recruit through initiatives that focus on minority enrollment in graduate programs	**41%** (7)	**29%** (6)	**34%** (13)
✓ Informational visits to minority colleges	**47%** (8)	**24%** (5)	**34%** (13)
✓ Undergraduate exchange programs with historically black colleges and universities	**18%** (3)	**29%** (6)	**24%** (9)
Recruit from summer programs around the country	**24%** (4)	**19%** (4)	**21%** (8)
Recruit through regional institutional initiatives	**18%** (3)	**19%** (4)	**18%** (7)
✓ Informational visits to women's colleges	**12%** (2)	**5%** (1)	**8%** (3)

Admissions

Principal Investigators were asked to indicate which factors were most important to the admissions process.[7] The top three factors were: recommendations (65 percent of PIs ranked as the most important factor), undergraduate grade-point-average (51 percent), and Graduate Record Examination (GRE) scores (46 percent).[8] When asked what other factors were used in admitting trainees to the program, a frequent response was a demonstrated commitment to conducting scientific research within the inter/multidisciplinary framework of the IGERT program, examples of which include the following:

> Since our IGERT program emphasizes thrust areas with students working as inter/
> multidisciplinary teams, we carefully evaluate the students for a fit in the IGERT program.
> Therefore, student motivation and intrinsic interests are evaluated during the interviewing
> process. The students are also evaluated in terms of their ability to interact in a team approach
> and their ability to understand and have interest in the global perspective of the project.

> We look at the undergraduate transcripts to see if the student combines strong ability in
> math/physics/engineering with a breadth of interests in other fields (Biology, economics, etc.).

> Because the value of the group experience relies heavily on the interactions among members
> over a substantial period of time (approximately four years) and the loss of a group member
> can negatively impact the quality of the research, the individual's commitment to the program,
> as measured by written and oral statements, is weighed heavily in the admissions process.

Several PIs explicitly mentioned "status as a member of an underrepresented group" as an important admissions factor. In the words of one PI, "We give priority to creating a diverse student body over consideration of traditional measures such as GREs and grades." Others desired to see evidence of prior research experience (for example, during undergraduate studies): "We are less concerned about grades and GREs than we are about demonstrated commitment to research, and therefore look for positive signs of the student's initiative."

Student Graduate Status at Funding

Across all IGERT projects, there were 305 trainees. Nearly half (45 percent) of these students became trainees at the same time they enrolled in the IGERT department, with their funding thus coinciding with the beginning of their graduate education. Of the remainder, 20 percent were enrolled in their IGERT department for one year before becoming an IGERT trainee, 15 percent for two years, and the remaining 20 percent for three or more years.[9] Several PIs commented, when discussing barriers to implementation, that in their first year they funded students already enrolled in their Ph.D. programs because they had no time to make special recruiting efforts for that year. Thus,

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[7] PIs were instructed to place a '1' next to the most important factor for admissions decisions, then a '2' and so forth. If a department's admissions committee put equal weight on more than one item, PIs could give those items the same ranking.

[8] The GRE scores of the trainees are impressive, averaging 682.78 for the Analytic section, 577.60 on the Verbal section, and 709.56 for the Quantitative section.

[9] The sixty-one trainees enrolled in a sponsoring department for three or more years before becoming IGERT-funded were distributed as follows: 27 for 3 years, 17 for 4 years, 8 for 5 years, 7 for 6 years, 1 for 7 years, and 1 for 8 years.

we might expect that the number of more advanced students being funded will decline as projects have time to recruit new students.

Trainee Retention

While IGERT trainee retention data will be more meaningful at the end of each five-year grant period, there is some preliminary information from this data collection. To date 13 trainees have received a Ph.D. degree associated with their IGERT project. On average, they took five and one half years to complete their degree from the time they enrolled, with a range of four to seven years. An additional 18 trainees dropped out of their IGERT projects, 2 with a terminal Master's degree. Five of these 18 individuals left to pursue other academic interests, 2 to pursue employment, 5 owing to failure to meet program requirements, and 6 for other or unknown reasons.

Trainee Academic Achievement During the Reporting Period

Doctoral studies place rigorous demands on students, and science and engineering students face considerable time constraints balancing coursework, laboratory research, and their own dissertation studies. Finding time to publish, present at conferences, or otherwise to communicate with colleagues in one's discipline is difficult and, when accomplished, can be taken as a sign of a committed scholar.

We asked trainees to tell us about their academic achievements as IGERT trainees, and the results were rather impressive. One-third (31 percent) of all trainees had published at least one article in a refereed journal, and nearly as many (29 percent) had published something other than a refereed journal article. Among individuals who published in a referred journal, the average number of articles was 1.9. One individual wrote a book, and 15 others (5 percent) published a book chapter. In addition, the trainees hold 11 patent applications and 2 approved patents.

In addition to written publications, the trainees as a group were actively involved at conferences. One in four (24 percent) of the trainees presented at a regional conference during this reporting period, and one in three (33 percent) presented at a national conference. Reflecting IGERT's emphasis on international connections, 18 percent of the trainees presented at an international conference. Given that many of these students were only in their first or second year of graduate school, their publication and presentation productivity is noteworthy. The fact that 21 percent of the trainees reported having received an award or other recognition during this period is evidence that others find these students commendable as well. It can also be noted that when compared to the IGERT associates, trainees were significantly more likely both to publish in a refereed journal and to present at regional and national conferences.

Section 3: Undergraduate and Graduate Participants

The IGERT Program Solicitation allows the participation of individuals at the undergraduate, master's, or postdoctoral levels, if such participation clearly strengthens the doctoral program. Funding may be provided through IGERT at the level of Research Experience for Undergraduates (REU) stipends for undergraduates and at whatever level the university deems appropriate for postdoctoral fellows. Accordingly, if their projects included either undergraduate or postdoctoral students, PIs were asked in the web survey to describe how such participation has strengthened the education and/or research experiences of their graduate students.

Exhibit 3.1 shows the distribution of postdoctoral and/or undergraduate student participation across cohorts. The largest proportion of project PIs (32 percent) reported neither undergraduate nor

Exhibit 3.1: Distribution of Inclusion of Undergraduate Students and/or Postdoctoral Students Across Cohorts.

| | Percent (n) | | |
| | 1998 | 1999 | All |
Category	n=17	n=21	n=38
Neither undergraduate nor postdoctoral students	**35%** (6)	**29%** (6)	**32%** (12)
Postdoctoral but not undergraduate	**24%** (4)	**14%** (3)	**18%** (7)
Undergraduate but nor postdoctoral	**18%** (3)	**29%** (6)	**24%** (9)
Both undergraduate and postdoctoral	**29%** (5)	**24%** (5)	**26%** (10)

postdoctoral participants. However, a nearly equal proportion (26 percent) reported both undergraduate and postdoctoral participants, while the remainder reported either only undergraduates (24 percent) or only postdoctoral participants (18 percent). Proportionally, the 1998 cohort exceeded the 1999 cohort in all categories except 'undergraduates but not postdoctoral students,' where the 1999 projects outnumbered the 1998 projects by a two to one margin.

Undergraduate Students

Of the 19 PIs who reported that undergraduate students were taking part in their projects, four commented that their undergraduates were either not supported by IGERT funds (two) or had not yet begun (two). Just over half of these 19 PIs wrote of summer or other time-limited activities for these students, such as REUs, summer internships, or specific short-term programs for undergraduates. Undergraduate activities were sometimes valued solely for their recruiting potential but, in other instances, PIs reported that their trainees played active roles in the undergraduate experiences, serving as mentors and providing information on graduate education and inter/multidisciplinary research.

> The Undergraduates are benefiting from an outstanding experience that is designed to attract them into science as a career. The graduate students benefit from the experience of working

with and mentoring the undergraduates. The experience of doing one-on-one teaching is invaluable as they develop into scientists and educators in their own right.

Where numbers of undergraduates were mentioned, PIs reported from 6 to 12 taking part in these summer programs.

Year-round undergraduate involvement in IGERT projects was also touted by PIs for similar reasons. Recruitment and mentoring opportunities for graduate trainees were frequently mentioned, as was experience gained by trainees "in communication and supervision."

Undergraduates do research that is directed on a day-to-day basis by the IGERT trainees. This gives the undergrads valuable research experience while giving the graduates experience in directing the work of others and making decisions based on the results obtained.

Postdoctoral Fellows

Three of the 17 PIs reporting postdoctoral participation added in textbox comments that they did not fund their postdocs through IGERT; two reported that they had not had postdocs active in their projects that year.[10] Two others reported their postdocs were only partially supported by IGERT funds. All have found multiple uses for postdoctoral fellows within their IGERT projects. Most commonly mentioned were roles mentoring trainees and roles in establishing research projects and promoting collaboration in research across disciplinary boundaries.

These postdocs have played a very valuable role in the training of the graduate students. They were designated specific mentoring roles in the ... Seminar, e.g. helping designated groups of students develop a project paper and presentation, and helping organize visits by outside speakers. In addition some of the associates have played very strong research advising roles for certain of the graduate trainees.

Others cited postdoc roles in organizing retreats, seminar series, or reading groups, facilitating travel to conferences, supervising projects, helping professors with courses and teaching their own courses in advanced subject areas. Two PIs mentioned the important role of postdocs in extending the expertise available to trainees beyond that provided by the faculty.

Postdoctoral trainees add expertise lacking in the faculty, which allows them to advise and sometimes co-supervise trainee research, and lead seminars on topics outside the area of expertise of the faculty.

As one PI expressed it, the postdocs serve as key guides and mentors who were present in the lives of the trainees on a daily basis, and provide a close professional association that might not have been available from faculty.

We find that postdocs provide an invaluable resource for the IGERT graduate students. Postdocs are present every day all day in the laboratory, and often have the time and patience to teach graduate students mathematics and programming techniques that are tremendously useful. The postdocs also serve as role models that the graduate students can relate to more easily than they can to faculty.

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[10]   One of those without active postdocs this year reports that the stipulation of only six months of funding per postdoc has made recruitment difficult for them and they are planning to move their postdoctoral funds to support more trainees.

Section 4: Early Outcomes

The IGERT traineeship program seeks to encourage innovation in graduate education by supporting the development of broad-based graduate education centered on an inter/multidisciplinary research theme. In addition to the traditional emphasis on excellent research skills, IGERT trainees are also expected to master communication and teamwork skills. It is expected that IGERT projects will broaden trainees' career horizons by exposing them to a variety of work environments, and increase trainees' understanding of and comfort level with individuals from other backgrounds and/or countries by allowing trainees to serve as members of collaborative partnerships and diverse research teams.

How successful have the IGERT projects been in furthering the IGERT program's goals? One answer lies in PIs' responses when asked to rate the extent to which their projects have fostered trainee growth on a scale of "Successful," "Somewhat Successful," "Not Successful," or "Not Begun." The results are summarized in Exhibit 4.1. Each of these elements will be discussed in greater detail later in this chapter, but an overview of how PIs assessed their progress in fostering trainee growth in these areas is useful. Because these projects were in their first two years of implementation, we have ordered the program goals in the table in such a way as to emphasize engagement rather than success in achieving these goals. Note that no PI ever rated his/her project as "Not Successful" on any element. While this should, perhaps, be interpreted cautiously because of the PIs' personal investment in the success of their projects, it is still encouraging.

Examining this ordering of program elements, it appears that NSF's expectation that projects will center their graduate education programs around an inter/multidisciplinary research theme is being met. Over 90 percent of projects have implemented the five activities associated with that goal. The majority of PIs rated their projects "Successful" when it came to fostering trainee growth in inter/multidisciplinary coursework (82 percent), functioning in an inter/multidisciplinary environment (88 percent), and communicating across disciplines (76 percent). Teamwork (70 percent) and breadth and depth of knowledge (67 percent) also fell into the group of new skills whose development is encouraged by the IGERT program. More PIs felt they had some way to go before they were successful in achieving breadth and depth of knowledge and team work skills than for the other skills in this group. This is probably a reasonable reflection of the beginning status of most of the trainees' graduate education.

The middle group of skills, dealing with research, instrumentation and technology, and professional communication are those more associated with traditional graduate education. The higher percentage of PIs who reported that they had not yet begun developing these skills is, again, probably a combination of the beginning status of many of the trainees and the likelihood that some of these elements are taught outside the IGERT project by other institutional entities.

It appears that fostering growth in professional skills in education (i.e., teaching and mentoring and course development) was a lower priority for these IGERT projects, since more than one-third had yet to begin implementing these program elements. This is in keeping with the fact that one impetus for developing the IGERT program was a desire to prepare science and engineering doctoral students for careers *outside* of academia.

The development of trainees' international perspective was the only item outside of education skills which appeared not to have received strong emphasis in the projects to date; nearly half (48 percent) of the PIs reported they had not yet begun to cultivate in their trainees familiarity with different cultural perspectives, ability to work with scientists from different cultures, or other international perspective experiences.

Exhibit 4.1: Project Success in Fostering Trainee Growth as Reported by Principal Investigators

Project Goals for Trainees	Total number of projects with trainees = 33[1]		
	Percent (n)		
	Not Begun	Successful	Somewhat Successful
Breadth and depth of knowledge	**3%** (1)	**67%** (22)	**30%** (10)
Ability to function in an inter/multidisciplinary environment	**6%** (2)	**88%** (29)	**6%** (2)
Success in inter/multidisciplinary coursework	**6%** (2)	**82%** (27)	**12%** (4)
Teamwork skills	**6%** (2)	**70%** (23)	**24%** (8)
Ability to communicate across disciplines and with different audiences	**9%** (3)	**76%** (25)	**15%** (5)
Familiarity with state-of-the-art instrumentation/technology/modeling skills.	**12%** (4)	**73%** (24)	**15%** (5)
Ability to communicate professionally (e.g., give presentations, write scientific articles)	**15%** (5)	**64%** (21)	**21%** (7)
Ability to conduct high-quality research	**18%** (6)	**70%** (23)	**12%** (4)
Teaching and/or mentoring	**36%** (12)	**27%** (9)	**36%** (12)
International perspective (e.g., familiarity with different cultural perspectives, ability to work with scientists from different cultures)	**48%** (16)	**15%** (5)	**36%** (12)
Course development	**55%** (18)	**24%** (8)	**21%** (7)
Other	**73%** (24)	**21%** (7)	**6%** (2)

[1] Of 38 projects, 5 reported not having trainees during this reporting period. Thus the exhibit is based on 33 projects.
Note: Percentages may not sum to 100 percent due to rounding.

From Exhibit 4.1 we gain a broad overview of how well PIs believed their projects were performing on various IGERT goals. In the next section of the report, we will examine a number of these goals in depth, seeking to compare PIs' reports of what has been implemented with trainee reports of actual experiences. We will first display the percent of projects with activities focused on these skills, and then the proportion of projects reporting that the educational activities were developed specifically for the IGERT program. We will also explore what approaches PIs report to have been most effective with their trainees. Then discussion will turn to the trainees' reports of activities in which they engaged in the past year to develop each set of skills, and which of these they found particularly helpful. We begin with the cornerstone of the IGERT program: inter/multidisciplinary efforts.

Inter/multidisciplinary Education: Breadth and Depth of Knowledge

The organizing principle of the IGERT program is to foster the expansion of inter/multidisciplinary research and education by exposing trainees to topics outside their own field of research and involving them in educational and research experiences with individuals from a range of disciplines. NSF hopes that an inter/multidisciplinary educational program will better prepare graduates for multiple careers. In this section, we ask how well and in what ways projects have implemented their inter/multidisciplinary themes.

Principal Investigators

PIs were asked whether or not their projects incorporated a series of activities aimed at increasing the inter/multidisciplinary nature of the IGERT experience for trainees and whether these activities were developed specifically for IGERT. Exhibit 4.2 displays their responses, listed in order of the

Exhibit 4.2: Inter/multidisciplinary Education of Trainees as Reported by Principal Investigators

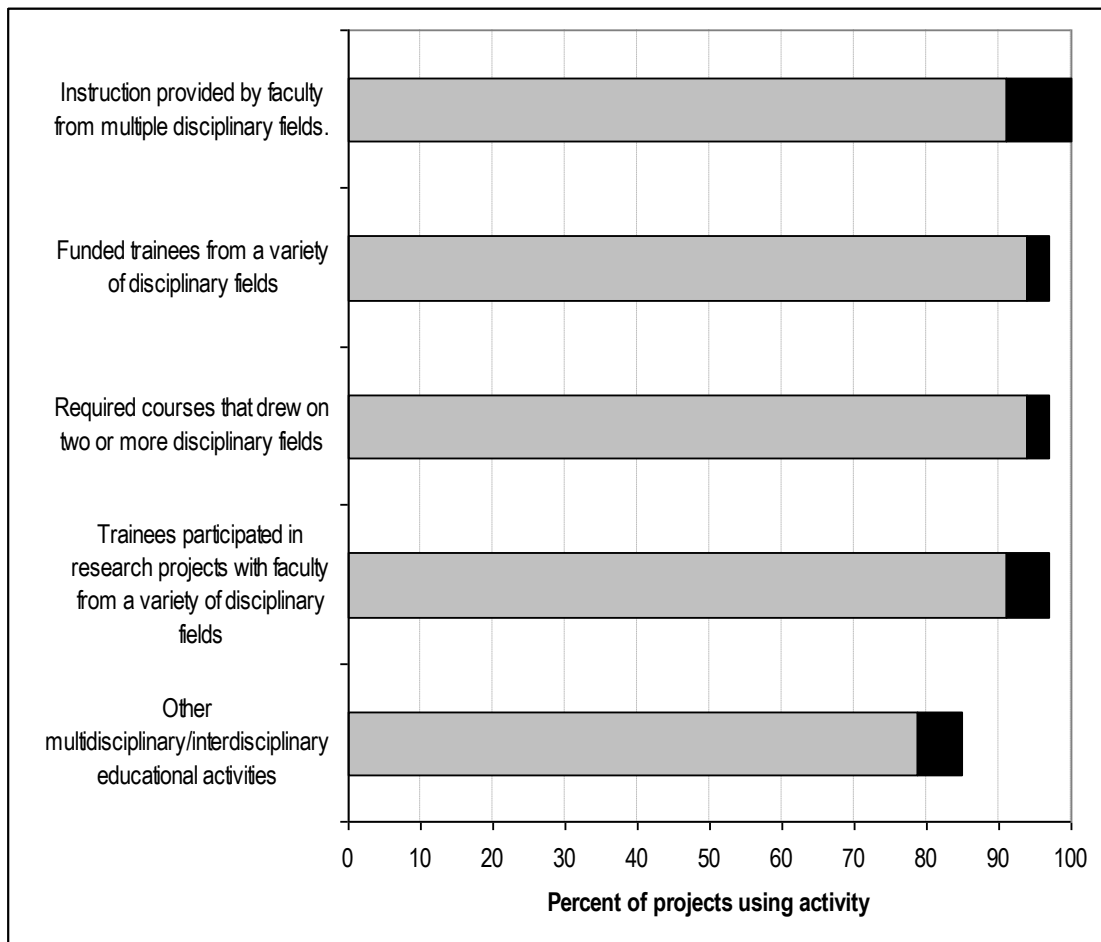Number of projects with trainees = 33

Exhibit reads: 100 percent of the PIs at projects with trainees report that instruction is provided by faculty from multiple disciplinary fields. Ninety-one percent of these projects (91 percent of the total number of projects) developed this activity specifically for IGERT.

frequency of their use by the IGERT projects, and the results are highly favorable. The vast majority of projects implemented the listed activities to provide their students with an inter/multidisciplinary background. Every project reported offering instruction by faculty from multiple disciplinary fields. All but one of the 33 projects with trainees reported funding trainees from a variety of disciplinary fields, requiring courses that draw on two or more disciplinary fields, and providing opportunities for trainees to participate in research projects with faculty from a variety of disciplinary fields.

More than any other activity type discussed in this report, the inter/multidisciplinary efforts underway in these projects were almost entirely instituted *specifically for the IGERT program*. Between 91 percent and 97 percent of departments who initiated inter/multidisciplinary activities did so with the inception of their IGERT projects.

The majority of project PIs also reported other inter/multidisciplinary activities used by projects, including: summer internships for trainees in industry settings; lab rotations; collaborative trainee projects; inter/multidisciplinary seminars and conferences; and lecture series where researchers from a variety of fields are brought in to speak with trainees. The most common type of activity mentioned was a seminar or colloquium series. These seminars varied in terms of length and format but all centered on the concept of exposing trainees to other disciplines, as described in one PI's comments:

> The core of our IGERT program is a 3-semester, inter/multidisciplinary proseminar in inequality & social policy. This proseminar draws essentially on 4 disciplinary fields (economics, political science, sociology, and public policy) to address a range of substantive topics pertaining to the causes and consequences of inequality. In so doing, the course also draws upon 30 members of the faculty from multiple disciplines who lead sections of the course in their area of expertise. Students gain exposure both to different disciplinary approaches to similar research problems and to the substantive insights and empirical findings of other disciplinary literatures.

PIs frequently referred to inter/multidisciplinary courses as an effective method of broadening trainees' perspectives. The format of these courses varied greatly in terms of whether trainees were required to attend; course size; course length (special one-day classes to year-long classes); and class structure (team-taught classes with students from several disciplines to courses with one professor and students from a single department).

> We found that a course that provided the foundations of the variety of disciplines participating in the IGERT program was effective in getting the students to know each other and to appreciate one another's backgrounds. A course in which professors from several disciplines presented current topics from those disciplines was also effective in helping the trainees understand the inter/multidisciplinary nature of the work. Our Social/Legal/Political Aspects of Environmental Science and Engineering course was very well received and broadened the students' perspectives. Scientists and engineers must learn the importance of these topics to function effectively in the field today.

> The course is team taught by faculty from biology, chemistry, math and computer science. It was designed in modules which were presented by single faculty or groups of faculty. Students were divided into teams [each of which] included students from biology, math and computer science. Overall the students learned a great deal from these team experiences. Because their backgrounds are quite different, they relied on each other to fill in the gaps in their knowledge of different subject areas.

In addition to these courses, departments also created laboratory rotations which exposed students to research methods used in other disciplines. One PI explained the benefit of rotations as "enabling our students to display a knowledge base distinctly different from the traditionally trained doctoral

student in chemistry, physics and engineering." PIs also praised the creation of research projects involving faculty from multiple disciplines. Many PIs reported that their programs required their trainees to either have faculty from two different disciplines on their dissertation committees or to actually undertake an inter/multidisciplinary research project with several advisors from different departments. Another common activity involved a team of students from different disciplinary backgrounds undertaking a research project with input from advisors and/or faculty members from different departments.

> The students are required to participate in inter/multidisciplinary collaborative projects. These must involve students and faculty from at least three disciplines, and should have a client organization that will benefit from the work. One full-time semester is devoted to the work.

From the PIs' responses to the survey questions as well as from their comments in the textboxes, it appears that almost all of the IGERT awardees have taken steps towards integrating inter/multidisciplinary activities into their degree programs.

Trainees

The inter/multidisciplinary flavor of each IGERT trainee's education occurs on several levels: interactions with individuals in other fields, taking courses in outside departments, and possibly earning an inter/multidisciplinary degree. Trainees were first asked whether they would receive their degree from an inter/multidisciplinary program or a single discipline department. Twenty-eight percent of the trainees reported they will graduate from an inter/multidisciplinary department.

Seventy percent of the trainees had taken at least one course in a department outside their own. Trainees could report taking classes in up to four different outside departments. On average, trainees took courses in two different departments. Forty-two percent of those taking outside courses took courses in only one outside department, 30 percent in two departments, 17 percent in three outside departments and 11 percent in four outside departments. The number of courses taken in an outside department ranged between 1 and 16, averaging 1.6. The average total number of outside courses taken (across all outside departments) was three.

When asked about other educational or professional experiences that have contributed to the "breadth and depth" of their knowledge, trainees spoke of: IGERT courses and seminars,[11] summer internships, training and job experiences prior to entering the IGERT program, research projects, conferences, and interactions with faculty and industry while enrolled in the IGERT program. In particular, trainees cited inter/multidisciplinary seminars and courses as exposing them to other fields.

> The proseminar in inequality and social policy…inspired me to pursue a truly inter/multidisciplinary project for my dissertation. Seeing traditional problems in economics discussed from the point of view of sociologists and political scientists made me realize the value of combining methods and frameworks across disciplines rather than limiting oneself to answering questions from the perspective of one field of thought.

Trainees also cited more informal interactions with their professors as valuable to their academic development.

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[11] Not surprisingly, many of the IGERT courses and seminars trainees mention as contributing to the breadth and depth of their knowledge are the same courses PIs mentioned as effective multidisciplinary training activities.

One particular aspect of the IGERT program that I like is the willingness of the faculty and students from other departments/fields to exchange ideas both formally and informally. The informal interaction takes place both during IGERT-organized retreats and group meetings as well as throughout the academic year. The faculty from different departments are almost always available to answer questions on topics on their areas, and they are open to discussion.

In addition to interactions within their home institutions, trainees often mentioned experiences outside of the classroom or institution lab as increasing the breadth and depth of their knowledge, citing a combination of programs, internships, and employment experiences. These experiences are described in more detail in the section on internships later in this report.

Preparation in Communication and Teamwork

A new cadre of doctoral graduates in science able to communicate across disciplinary boundaries and with different audiences, as well as in the traditional scholarly mode, is one of the goals of the inter/multidisciplinary IGERT program. Both the PI survey and the trainee survey contained sections dealing with these skills, so vitally important to extending research beyond disciplinary boundaries to team efforts in business, industry, and the public sector.

Principal Investigators

Exhibit 4.3 displays PI reports of project trainee preparation activities in the area of professional communication and teamwork. These are listed in order of the frequency of their use by the IGERT projects. Note that all of the specified trainee preparation activities in Communication and Teamwork were used by 80 percent or more of those projects with trainees. The three most frequently used (90 percent or more) are those most integrated into the daily schedule of graduate education in an inter/multidisciplinary mode: communication across disciplinary boundaries, in-house experience with oral presentations, and team educational or research ventures. External presentations of work, both at professional conferences and in refereed journals were also commonly used at the projects. Coursework/training in professional writing with regular faculty feedback was the least commonly employed (though 82 percent is still a significant number of projects), although it seems likely that some sort of faculty feedback must have preceded publication of journal articles.

Although over 50 percent of those employing any of these activities reported that the activity was developed for the IGERT project, some were clearly more heavily IGERT-inspired than others. The trainee preparation activities cited most frequently as being developed for IGERT were those with inter/multidisciplinary emphases, and those beyond the expected (listed as 'other' in the survey). In contrast, projects requiring students to publish research papers in refereed journals or take coursework in professional writing were more likely to have already had such activities in place before IGERT.

When asked which activities they found particularly effective in enhancing trainees' skills in professional communication, one PI commented that their trainees are too early in their graduate education to present at national conferences, but that they sent "students to professional conferences and workshops for exposure to science on a national and international scale." This emphasis on the development of skills that will be used later in publishing or at professional conferences was a common theme.

[Our] IGERT makes use of a cohort approach for the genesis and conduct of research in which members of a group from various backgrounds interact as they define and conduct their research. This places considerable emphasis on the development of communication skills among cohort members and their faculty mentors.

Exhibit 4.3: Trainee Preparation in Communication and Teamwork as Reported by Principal Investigators
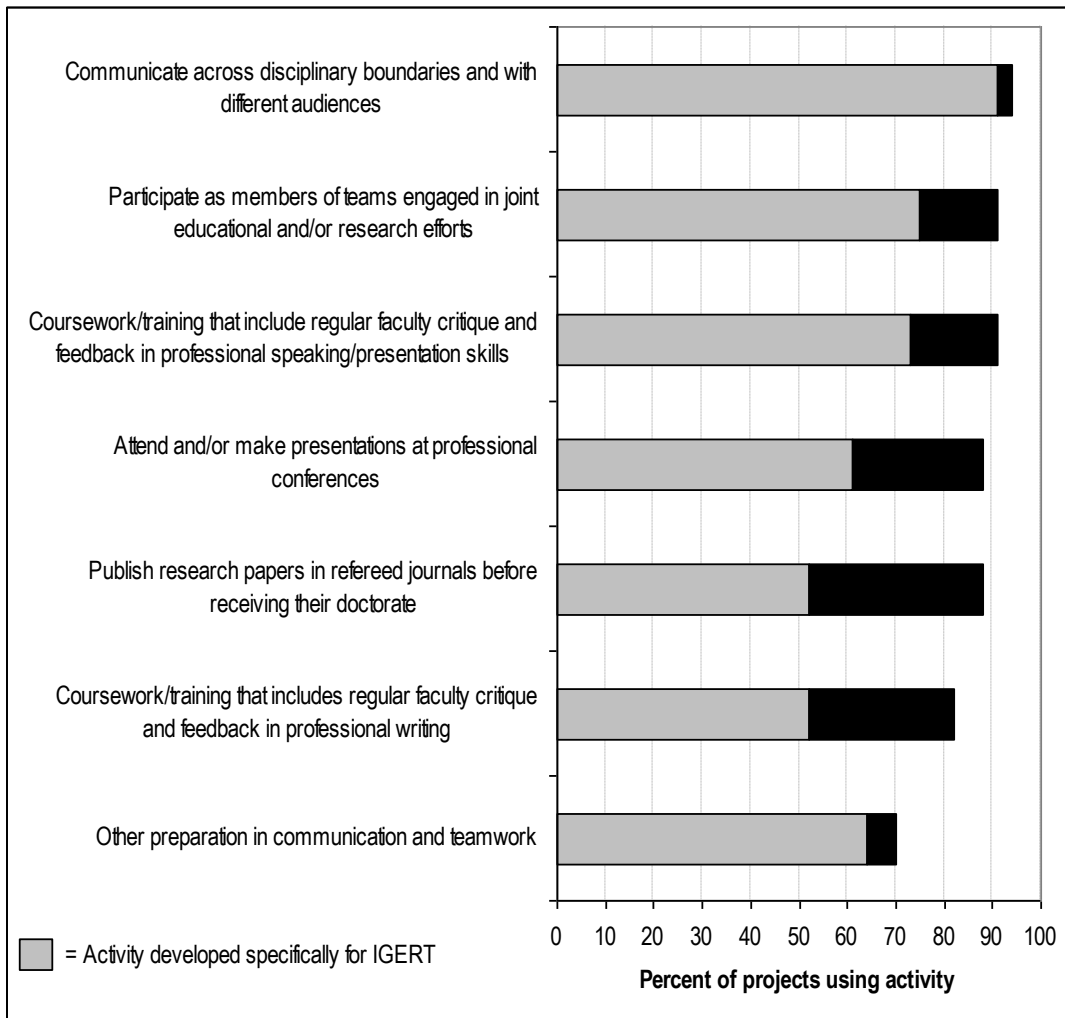
Number of projects with trainees = 33

Exhibit reads: Ninety-four percent of the PIs at projects with trainees report that trainees receive experience in communication across disciplinary boundaries and with different audiences. Ninety-seven percent of these projects (91 percent of the total number of projects) developed this activity specifically for IGERT.

[Each student] critique[s] a presentation on a topic of interest to him or her, but from a different disciplinary background. This is an important, an often neglected, aspect of professional development. Students need to learn how to think on their feet and fashion a coherent critique of complex material, a skill that is in perpetual use among faculty, leaders in the public sector, and virtually all professionals.

Our student seminar series has been a particularly effective means of enhancing inter/multidisciplinary communication and teamwork.... We find that the students are remarkably willing to conduct research outside the boundaries of their prior training. For example, one of our IGERT fellows (a biologist), presented a seminar describing his very successful research

rotation in computer engineering that required sophisticated understanding of genetic algorithms. In another example, a molecular biologist described an algorithm she developed to identify distinct functional domains of a protein. Her idea excited a computer scientist in the course, who was able to write graphics software to map the functional domains onto the protein's crystal structure. A statistics student then developed a way to assess the significance of the program's output. We anticipate a joint publication will result from their combined efforts.

In the social, legal and political aspects of environmental technology course, the students role-play various constituent groups. So, for example, one student was asked to represent Native American interests, another the EPA, another a farmer in a community, and still another a Department of Energy official.

Trainees

Trainees' reports of what they actually experienced (presented in Exhibit 4.4) indicate the effective implementation of activities envisioned by the PI and faculty designers of the project. However, remember that we are looking at summary figures in both sets of responses, and are therefore missing the degree of match or mismatch in individual projects. The most prevalent activities, reported by more than 60 percent of the trainees, were attending professional conferences and presenting at their own institutions. Fewer trainees reported making oral (44 percent) or poster session (30 percent) presentations outside their home IGERT institution, and roughly one-third (34 percent) had received some kind of education or coursework in professional speaking or presentation skills. In addition, nine percent of the trainees did not report experiencing any of the activities listed in Exhibit 4.4.

Exhibit 4.4: Trainee Reported Participation in Activities Intended to Develop Ability to Communicate Professionally

Educational/Professional Activities	Percent Who Reported Activity (n=305)	Average Number Reported (of those using activity)
Professional conferences attended	62%	2.1
Presentations made at the IGERT institution	61%	2.8
Oral presentations outside the IGERT institution	44%	2.3
Training/coursework in professional speaking/presentation skills	34%	n/a
Poster session presentations outside the IGERT institution	30%	1.7
Training/coursework in professional writing	23%	n/a
Other activities to develop or increase your ability to communicate professionally	17%	2.2

Note: 305 trainees in 33 projects responded.

While 88 percent of PIs reported that their projects send trainees to conferences, 62 percent of trainees reported actually attending conferences. Allowing for the fact that not all students in a program are likely to attend a professional conference in any given year, this seems a reasonable

consistency of data across the two surveys. Trainees spoke of the benefits of attending professional conferences:

> Attending professional conferences allows one to see how to give an effective presentation, and equally importantly, how not to give a presentation.

> National Conferences allowed me to interact with the scientific world, and... to be confident about my research topic.

as well as the benefits of presenting poster sessions and papers to outside audiences:

> The poster session ... was particularly useful, both in learning how to organize info in such a medium, and in beginning to network with other scientists doing related projects in the region.

> My presentations have afforded me opportunities to explain my research to people not familiar with my field. Poster sessions are particularly helpful, since you are constantly having to explain the same things over and over.

> ... This was a presentation to a large audience of over 400 people ... of both technical and nontechnical backgrounds. It ... gave me the opportunity to practice presenting my research in a way that it could be understood by a broad audience.

Many trainees wrote of giving oral presentations to diverse groups, such as:

X   knowledgeable scientists in their own field of expertise in their own institution or at professional meetings,

X   peers and faculty in other departments associated with their IGERT project,

X   work groups in their industry, business, or public sector intern placements, and, less often, to

X   non-technical audiences.

Not surprisingly for new projects, many of whose trainees are in their early years of graduate education, presentations within the IGERT institution were most frequently mentioned (experienced by 61 percent of all trainees). Here are some of the trainees' assessments of the usefulness of these experiences, both within classes and department events they might share with other graduate students, and in IGERT-specific events.

> Although I didn't count this as "training" for professional presentations, it is quite common to give practice talks in my department both in order to prepare us for the upcoming talk, and to give us an opportunity to brainstorm possible responses to questions that may arise. I have found this to be particularly helpful in developing a style for giving presentations.

> Preparing and delivering my thesis proposal to the IGERT faculty helped me to focus my ideas about my thesis, and it forced me to justify its relevance before a rather large audience. The experience taught me a great deal not only about communicating technical matters, but about communicating enthusiasm, which it seems you have to be able to do if you want anyone to pay attention to a technical discussion.

Other trainees reported that their presentations to inter/multidisciplinary IGERT audiences reinforced "the need to be aware of [their] audience, and chose [their] words/descriptions accordingly," and helped them to "think more critically" and "express [their] thoughts more carefully." Interestingly, only 34 percent of trainees reported *training/coursework* in professional speaking/presentation skills, though those that did wrote in praise of the experiences. It is not clear whether the trainees who reported no speaking or presentation training did not consider the faculty and peer critiques spoken of in the text boxes as "training," or simply did not have such experiences.

All of the trainees in 21 of the 33 responding projects (64 percent of the projects) reported some activity to enhance their professional communication ability. In the other 36 percent of the projects (n=12), not all trainees experienced educational/professional activities in this area. Of these, there were six projects where one trainee (from 5 to 33 percent of the project's trainees) reported no such activity, and in the other six more than one of the trainees (between 2 and 4 individuals, representing 23 to 40 percent of their project's trainees) reported no such activities. As might be expected, five of the six cases where more than one trainee reporting no activities were newer projects funded in 1999.

A few activities cited as major emphases by the PIs were not captured in the trainee list of activities, but did stand out in trainees' textbox reports of which activities had enhanced their communications abilities. This was especially true of opportunities to communicate across disciplinary boundaries and to different audiences, opportunities to give oral presentations and receive critical feedback, and opportunities to work with other students and faculty in teams.

Preparation to Conduct High-Quality Research

Educating students to conduct high-quality research is the core element of doctoral studies in general, and a cornerstone of the IGERT program. Thus, PIs were asked whether their IGERT projects incorporated a series of activities focused on the conduct of high-quality research. How well are the projects educating students in research skills? Exhibit 4.5 displays PIs' reports of whether or not their projects included a series of activities which furthered the development of trainee research skills. Note that 70 percent or more of the PIs reported incorporating each of the specified trainee preparation activities in Conducting High-Quality Research. All but one or two projects (94 percent or more) reported providing coursework or other education in research methods and in state-of-the-art instrumentation, traditional elements of graduate education, while coursework or other education in ethical research and in statistics were provided by fewer projects (73 and 70 percent, respectively). Interestingly, over 80 percent of the PIs reported that their coursework/education in research methods and in instrumentation was developed specifically for their IGERT project, while only two-thirds reported developing their ethical conduct of research work for IGERT. This may be evidence of education in research methods specifically related to the inter/multidisciplinary research themes of the IGERT projects. Statistics coursework/education appears to have already been in place in most institutions.

Principal Investigators

In keeping with the goal that research education in these projects has a strong inter/multidisciplinary focus, many PIs reported that their IGERT programs include some kind of lab rotation (under which students rotate through laboratories in different disciplines) or seminars in which students have the opportunity to meet and talk with professional researchers in a variety of fields. As expressed by one PI, such activities aim to "pique [trainees'] interest in the various areas of research represented by the

faculty." Another PI's hope was that a broad introduction to research methods would "lower the barriers to trying new techniques and give students a much broader range of research options in their thesis work."

Almost three-quarters (73 percent) of the PIs reported educating students in the ethical conduct of research, of whom roughly two-thirds developed the activities specifically for IGERT. Referring to these activities, one PI reported,

> Responsible conduct of research education is especially useful [for trainees to learn] as many students have not previously thought of these issues. We work through materials prepared by the National Academy of Sciences, having the students consider the case studies presented there. Very interesting discussions!

Exhibit 4.5: Trainee Preparation in Conducting High-Quality Research as Reported by Principal Investigators

Number of projects with trainees = 33

Trainees receive coursework/training in:

□ = Activity developed specifically for IGERT   **Percent of projects using activity**
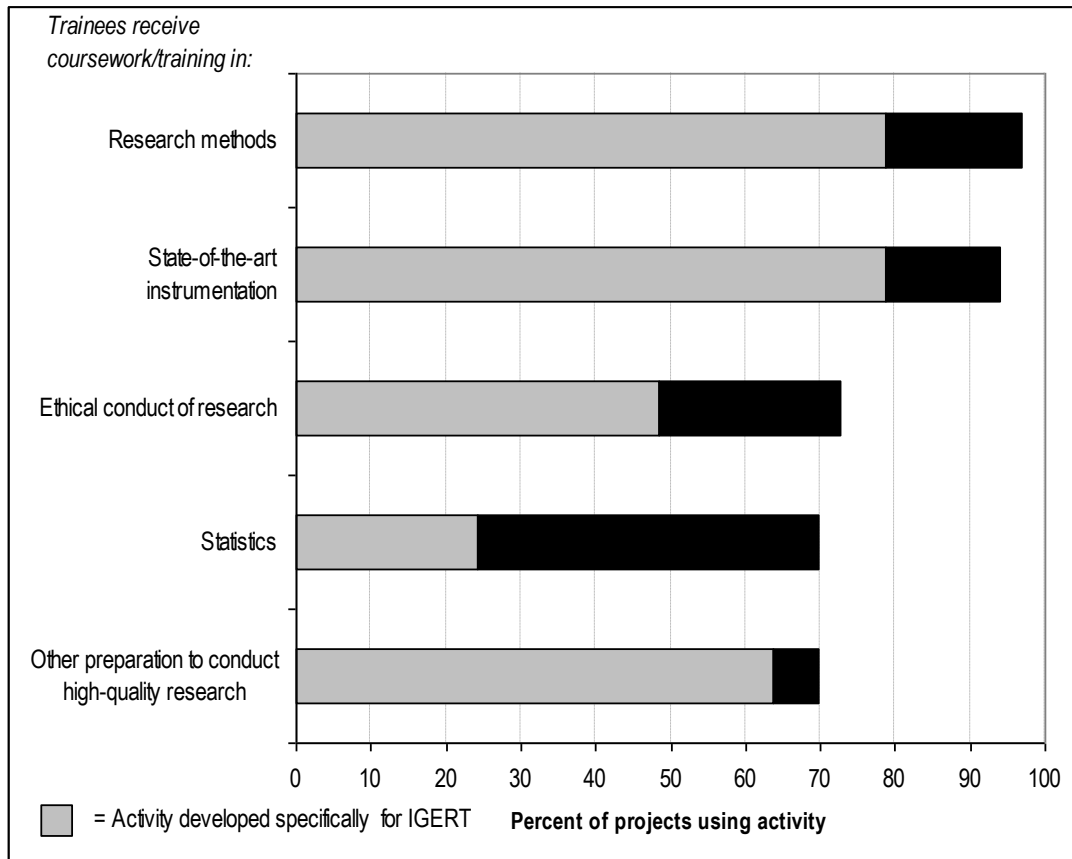
Exhibit reads: Ninety-seven percent of the PIs at projects with trainees report that trainees receive training or coursework in research methods. Eighty-one percent of these projects (79 percent of the total number of projects) developed this activity specifically for IGERT.

Another project PI describes conducting a day-long workshop on research ethics at the IGERT institution, addressing questions of: "whether one's values should or should not shape research choices, how one deals with unsettling findings…, [and] the ethical dilemmas of translating research into policy."

Overall, IGERT PIs were strongly confident that their projects train students to conduct high-quality research, and reported having developed numerous activities specifically for the IGERT program to further this goal. While this is encouraging, we must take note of the fact that the trainees themselves did not report participating in these activities at the same rate that PIs reported providing them.

Trainees

Exhibit 4.6 presents the percentages of trainees who reported experiencing various research-oriented activities. For each activity the trainees at projects whose PIs confirmed the existence of the activity were examined. For example, for the first activity, "training or coursework in research methods," 32 out of 33 PIs at projects with trainees reported that their trainees received training or coursework in research methods, and 48 percent of the trainees in those projects said they had received training or coursework in research methods.

Exhibit 4.6: Trainee Reported Participation in Activities Intended to Develop the Ability to Conduct High-Quality Research

Focus of Training or Coursework	Column A Percent (n) of projects whose PI reported activity was used Total N = 33	Column B Number of trainees at projects listed in Column A	Column C Percent of trainees listed in Column B who reported experiencing the activity
Research methods	97% (32)	299	48%
Responsible conduct of research	73% (24)	211	44%
State-of-the-art instrumentation	94% (31)	268	43%
Statistics	70% (23)	215	40%

Exhibit reads: The PIs at 97 percent of 33 projects reported that trainees at their projects received training or coursework in research methods. There were 299 trainees at those 32 sites, of whom 48 percent reported having participated in a research project involving multiple disciplines.

Even though their PIs reported that their projects were active in developing trainees' abilities to conduct high-quality research, less than half of the trainees within those projects reported having experienced these activities. There are several possible explanations for this, including: (1) that trainees were too early in their graduate study to focus on research, or (2) that trainees did participate in such activities but failed to directly attribute to them the purpose of developing research skills. Alternatively, PIs' reports of their program activities and opportunities for trainees may have exceeded what the trainees actually experienced.

Trainees were also asked about educational activities not included in the PI survey. For example, sixty-three percent of all trainees reported that they had participated in research projects outside of their own dissertation research. Examples of these experiences from trainee comments included:

> Although my home department is Civil/Environmental Engineering, I am a Ph.D. student in the Graduate Group in Ecology. Most of the research work I do for my research assistantship is not related to my dissertation work. During this reporting period, I (along with another research assistant) researched and wrote a report for the CA Department of Transportation

regarding vehicle driving cycles. Subsequently, we wrote a paper for a peer-reviewed journal on the same topic.

I have performed consulting projects for the Japanese and Swedish governments, and the Union of Concerned Scientists….

[I participated] in a research project nearly unrelated to my field of interest […which] will result in a published paper by the end of the year 2000.

One trainee reported trying "to broaden my knowledge and experience" by doing research with professors in two different departments. Another student echoed the IGERT founding principles, writing, "I think it is very important to pursue other areas outside of my dissertation. Too many people become focused on 'head of the pin' topics." And a third student praised IGERT: "Exposure to research areas outside of my background has helped me to think outside of the box and to learn the importance of detailed documentation, attention to details and time management."

Given the beginning graduate status of most of these trainees, it is not surprising that coursework (either in statistics or research ethics) and instrumentation training appeared most frequently in the trainees' text comments. Trainees reported that their methods courses were useful from a laboratory standpoint and their ethics courses intriguing and stimulating intellectually. Trainees also mentioned research seminars as a common means of learning how to conduct research:

Our program provides the opportunity to attend bimonthly seminars covering topics from ethics to presentation to grant writing. These seminars are quite informative and help to guide us in our efforts to be successful researchers.

Eighty-seven percent of the trainees reported experiencing at least one educational activity focused on preparation to conduct high-quality research. The remaining 37 individuals were most often isolated as the only person at their project site not having experienced any of these activities. The others represent 10 to 20 percent of the total number of trainees at their respective institutions – not an insignificant amount but not overly worrisome, either, as it is possible that they were still in the course-taking phase of their graduate studies.

Professional Skills in Education

In traditional doctoral programs, graduate students are prepared for the professorate largely through exposure to academic life and the example of their major professors. To what extent do the IGERT projects extend this traditional preparation for academia? Are trainees instructed in teaching practices? Do they continue to teach and mentor other students even as their instructional programs are expanded to include interaction with non-academic industry and government research projects?

Principal Investigators

Exhibit 4.7 displays responses from the PIs to questions of whether their projects included experiences aimed at preparing trainees for academic careers. While trainees at all but three projects gained classroom experience by serving as teaching assistants, it was generally less likely for the IGERT projects to explicitly train students in professional education skills than for research or other career-

focused skills. For most activities, less than half of the PIs reported offering these experiences, with generally less than 30 percent having developed the activities specifically for IGERT. Overall, fewer PIs reported these activities than any others examined in this report.

In contrast to explicit courses, examples of effective preparation for academic careers most often cited by PIs included trainee mentorship of undergraduate students, mandatory evaluation of trainees' teaching efforts (through seminar classes, videotaping, advisor meetings), and trainee attendance and participation at national conferences. "Trainees are pushed to attend and contribute to professional conferences," wrote one PI. "We find this is among the most powerful means of preparing students to meet the challenges of a faculty career."

Exhibit 4.7: Trainee Preparation in Professional Skills in Education as Reported by Principal Investigators
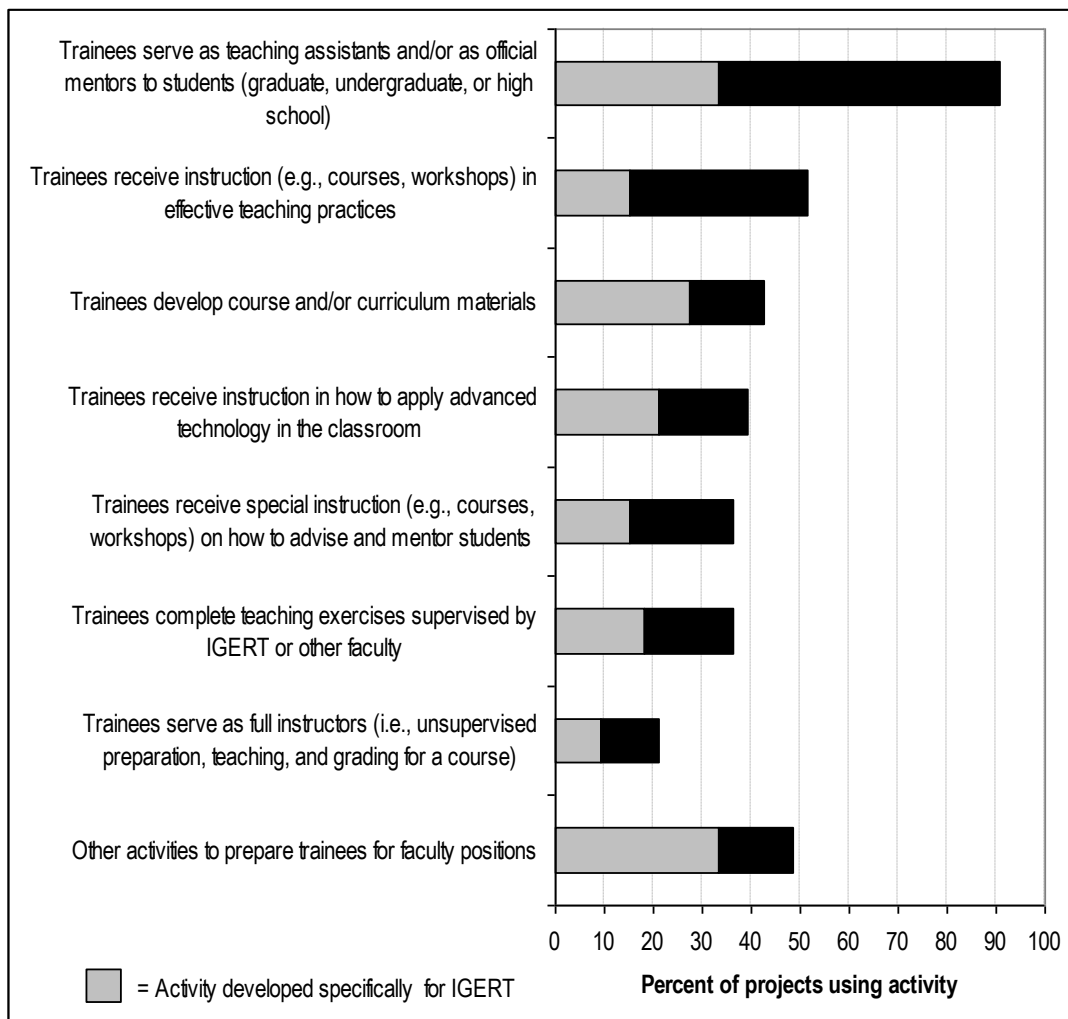
Number of projects with trainees = 33

Exhibit reads: Ninety-one percent of the PIs at projects with trainees report that trainees serve as teaching assistants and/or as official mentors to students. Thirty-seven percent of these projects (33 percent of the total number of projects) developed this activity specifically for IGERT.

Other PIs cited courses or seminars on teaching skills or broader topics, such as "Preparation for a Faculty Career." "Survival Skills" seminars were offered at one institution, covering topics such as "mentoring, teaching skills, postdoctoral opportunities, the grant process, grant writing, academic research/teaching careers, and industry opportunities." One PI mentioned the interaction of preparing for an academic career with IGERT's inter/multidisciplinary focus: "Probably the most notable results of IGERT in this domain are that a few of the doctoral trainees are bringing their own inter/multidisciplinary training to bear on the design of undergraduate seminars"–an example of a possible institutional impact of the IGERT program.

The IGERT program also emphasizes the development of skills in teamwork and group problem solving. Thus, it is encouraging to receive reports from PIs describing such efforts. For example, one project incorporated collaboration skills into its mentoring program:

> One unique aspect of mentorship in this program is the obligation of all ... graduate students to co-mentor each other as needed to succeed in courses outside of their undergraduate area of emphasis. For a student to be accepted into .. [this] graduate program they must agree to accept responsibility for the academic success of all ... students [in the program], not just their own success.

Overall, activities aimed at preparing trainees for academic careers were reported by IGERT PIs to be less prevalent than those aimed at other IGERT project goals. PIs offered several explanations for this difference. One of the frequently cited advantages of the IGERT traineeship was that often trainees were not required to teach in their first year, allowing them to focus instead on experiencing a variety of research fields, laboratory environments and techniques. As reported at one project, trainees are "occupied with their research rotations" during the first year of graduate study, and will "fulfill the teaching assignments required by their major departments" in subsequent years. In most cases, each student's sponsoring department, and not the IGERT project, set graduate student teaching requirements. For example, as one PI reported, "[t]rainees are accepted into individual departments, whose teaching requirements vary….These requirements are not administered by the IGERT, but by the individual constituent departments."

Trainees

Given the moderate focus on preparing trainees for academic careers described by the PIs, one might expect low proportions of trainees to have reported participation in these activities, and indeed we found this to be the case. In fact, almost one third (30 percent) of the trainees did not experience any of these activities.

Students were asked whether they had experienced educational/professional activities aimed at providing them with professional skills in education (i.e., preparing to be a faculty member). As shown in Exhibit 4.8, among the two-thirds who experienced at least one such activity, the two most frequently cited activities were teaching assistantships and mentoring of other students, both experienced by roughly one-third (36 percent) of the trainees. As might be expected, given that many of the trainees were only in their first or second year of graduate education, teaching experience would more often occur in the form of an assistantship than having complete responsibility for an academic course. Several trainees wrote in praise of their assistantship's value:

> My experience as a TA taught me to think from the students' perspectives. Also, the experience helped me to learn the materials better myself in order to find more effective ways to challenge the students and help them to really think and learn the material.

I feel that the teaching assistantships I have done have given me a better idea of the kinds of problems an undergraduate student typically faces. We have quite a bit of contact with the students, and I have come to better understand methods of teaching that might make some of the more difficult ideas ... easier to understand.

Exhibit 4.8: Trainee Reported Participation in Activities Fostering Professional Skills in Education

Educational/Professional Activities	Experienced *Trainee n=305* percent (n)
Teaching Assistantships	**36%** (110)
Mentoring of high school, undergraduate, or other graduate students	**36%** (111)
Participation in any inter/multidisciplinary course development, teaching, or other educational effort	**22%** (66)
Participation in any group education efforts (e.g., team teaching, teamwork on course development)	**17%** (52)
Courses developed and/or major teaching roles	**16%** (49)
Other activities to develop or increase professional skills in education	**13%** (40)

Note: 305 trainees in 33 projects responded. 92 (30%) of these reported no educational/professional activities in this area.

Serving as mentors to other students was also valued by trainees, who wrote that from mentoring they learn how to be better educators: "Mentoring others forces one to organize research. Also, I feel that more is accomplished because the mentees are constantly asking challenging questions." Another perspective, offered by a trainee who tutored three individuals, was that one-on-one sessions with mentees "enabled me to gain a new perspective on the different ways individual students learn. I believe it is important to understand these differences before moving on to large scale course development…."

One fifth of the trainees (22 percent) participated in inter/multidisciplinary educational efforts of some type (e.g., teaching, course development), and slightly fewer (17 percent) in group education efforts (e.g., team teaching), both of which are IGERT program objectives. Given that these IGERT projects are only one or two years old, it is encouraging that some of their students are already participating in these activities. At one institution, students were designing an inter/multidisciplinary course "that will address an inter/multidisciplinary scientist's need for competence outside of his or her field of specialization." At another site, students worked in a team with other graduate students on several projects, each teaching the other team members whatever essential material fell under their own area of expertise. And a third student echoed the importance of his/her project's inter/multidisciplinary focus, explaining that in demonstrating a laboratory experiment for fellow graduate students, "the experiments would not be possible without the assistance of other departments."

Preparation for Careers in Industry, Government, or the Public Sector

The IGERT program is "intended to facilitate the establishment of innovative, research-based graduate programs that will train a diverse group of scientists and engineers to be well-prepared to take advantage of a broad spectrum of career options."[12] These career options span multiple arenas, including the public sector as well as private for-profit industry and research. Communication skills and the capacity to work in inter/multidisciplinary problem-solving teams are important for success in such careers. Exposure to different job experiences through internships or other work experience outside of their institution can give trainees familiarity with non-academic careers and lead to employment opportunities.

How well are trainees being prepared for careers in industry or the public sector? Are they exposed to different fields of work, through partnerships with the public sector and industry? Are they gaining the skills needed to succeed in such jobs – communication, for example, with non-academic audiences?

Principal Investigators

To answer these questions we turned first to the PIs of each project, and asked them whether or not their projects provide a series of activities focused on preparing trainees for careers in industry, government, or the public sector. Exhibit 4.9 summarizes these responses, first indicating what percentage of projects used each approach, and then (of those using the approach) how many developed the activity specifically for the IGERT program.

To prepare trainees for non-academic careers, IGERT encourages two approaches: (1) provide trainees with important skills (e.g., communication, comfort working across disciplines, teamwork skills), and (2) expose trainees to alternative career opportunities outside of academia. In Exhibit 4.9, we see that almost all of the projects provided opportunities fostering important *career skills* in trainees, as illustrated by the following activities. One hundred percent of projects with trainees expected their students to participate in research projects involving multiple disciplines. Since the primary goal of IGERT centers graduate education around an inter/multidisciplinary research theme, this figure is expected, and confirms that IGERT is being implemented as intended. Equally as encouraging are the high numbers (94 and 88 percent, respectively) of projects in which trainees have experienced communicating across disciplines and/or with different audiences and have participated in team research efforts — both identified as important skills for careers in non-academic settings.

Exposure to opportunities for employment outside of academic settings is the second prong of preparing trainees for non-academic careers. Here, too, the project PIs reported strong efforts. Nearly two-thirds (64 percent) of the PIs indicated that their trainees participated in some type of application of research to industry or public policy. The same percentage of the projects arranged educational interactions with government/public sector or with industry professionals. One example of these kinds of interactions, as explained by a PI, included having personnel from a DOE national laboratory help teach a course on the "social, legal, and political aspects of environmental technology." This project also had industry and governmental agency personnel serve on a "technical

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[12]   Program Announcement, 1998.

advisory board" before which trainees made presentations and received feedback, thus gaining interaction with individuals outside of the academic world.

Exhibit 4.9: Trainee Preparation for Careers in Industry, Government, or the Public Sector as Reported by Principal Investigators

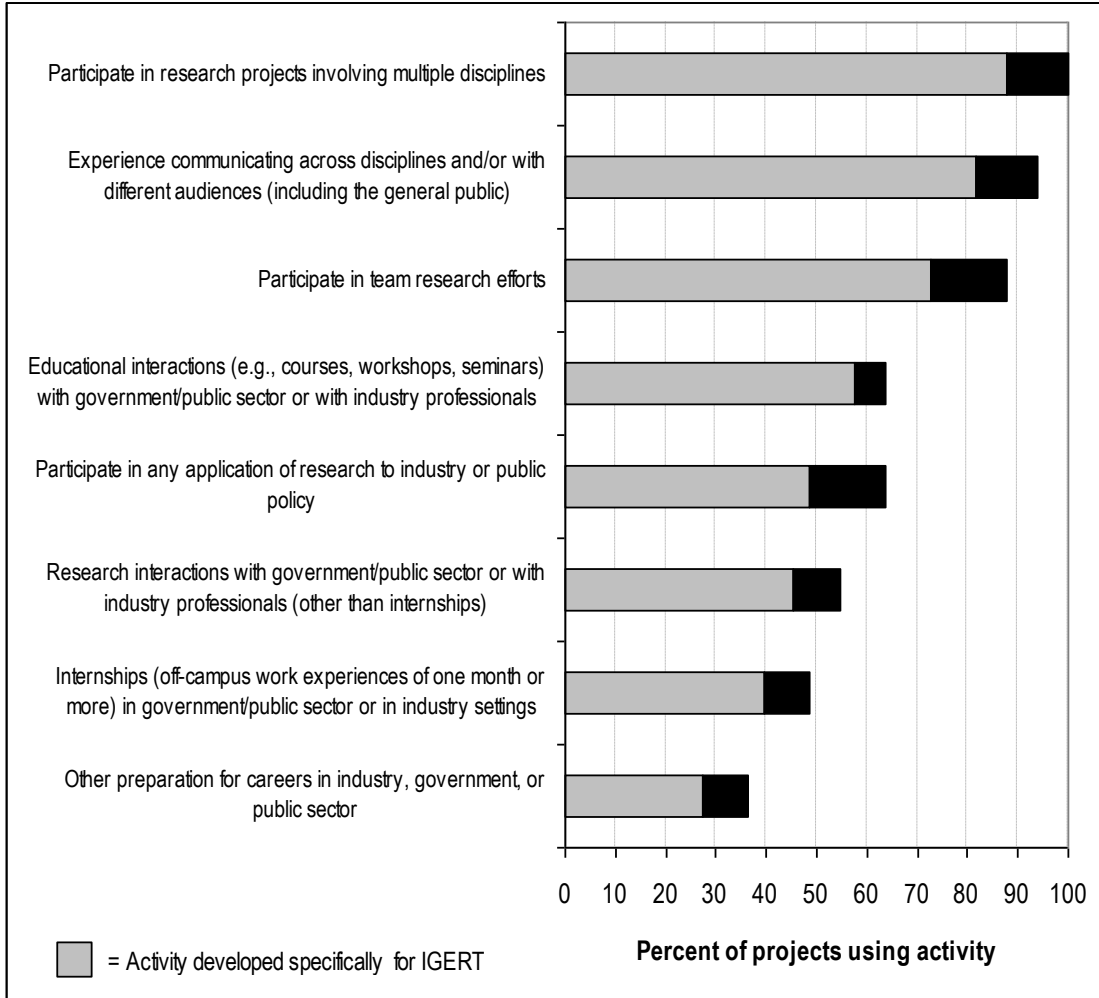Number of projects with trainees = 33

Exhibit reads: One hundred percent of the PIs at projects with trainees report that trainees participate in research projects involving multiple disciplines. Eighty-eight percent of these projects (88 percent of the total number of projects) developed this activity specifically for IGERT.

About half of the PIs indicated that research with nonacademics, either in the form of internships or through other interactions, was a part of their IGERT project. Just under half (48 percent) reported trainee internships in the public or industrial sector, while 55 percent reported some other form of research interactions with individuals in these sectors. At one site, for example,

> [S]tudents work in research teams with industrial partners (Delphi and Ford). They are benefited by direct interaction with industrial scientists and attend industrial seminars, group meetings and project report meetings. This serves as an invaluable experience in real world research.

The fact that these projects were only in their first or second year, and that many of their trainees were just beginning their graduate studies, very likely affected participation in these external research

opportunities. Several PIs reported that, although such interactions are offered, no trainees took advantage of them during the reporting period.

High percentages of the projects reported having developed these educational activities specifically for the IGERT program. Clearly, before IGERT funding existed, opportunities of this sort were not a standard part of science and engineering doctoral education. It seems that IGERT is having an impact on the educational experiences available to these students.

Although the issue was not directly addressed in survey questions, many PIs reported in their textbox comments that their projects provided *information* about non-academic careers to their trainees, either in the form of seminar classes or discreet workshops. At one site trainees attended a "Survival Skills Seminar" which covered "post-doctoral opportunities and careers in industry and government as well as a host of other survival skills topics." At another, a seminar series providing students with "an overview of career options in academia, industry and government labs" was developed, in which each speaker devoted part of their presentation to "career issues and advice." This trend implies that while projects may not yet have instituted direct interaction between trainees and non-academic (industry and public) personnel, they have begun educating trainees about the variety of careers available other than university faculty positions.

Trainees

While PIs were asked to comment on internship opportunities provided by their projects in the same survey section as that addressing other interactions with industry and the public sector, IGERT trainees addressed these two aspects of exposure to non-academic careers separately. In this section of the report, we will first consider trainees' reports of these activities excluding internships, and then report on their longer-term internship experiences.

Non-Internship Experiences
Trainees reflected their PIs' responses when they answered questions about their participation in activities intended to develop professional skills applicable to careers in industry, government or the public sector. Trainees were asked whether they had experienced a series of activities similar to those posed to PIs (Exhibit 4.10 presents these results) and then to comment on any activities which they felt had been particularly effective in enhancing their professional skills applicable to non-academic careers.

While every PI reported having research projects involving multiple disciplines, 71 percent of trainees reported participating in such projects. Similarly, 88 percent of PIs reported team research efforts, while 69 percent of trainees at those sites reported this activity. A greater discrepancy occurred in PIs' perceptions of teaching cross-discipline communication skills (94 percent), and trainees' reports of experiencing such education (48 percent). This may reflect the earlier noted tendency of trainees not to identify IGERT brown bags or seminars as *formal education* in cross-discipline communication.

Many trainees, when asked to comment on any activities that significantly enhanced their professional skills in this area, cited coursework or laboratory experience. The most frequently cited skill improvements were teamwork and communication skills. Trainees wrote about working on teams both with other students and in internship settings, and about communicating across a wide range of audiences, from other students in fields outside their own to industrial or public sector professionals outside of their institution.

Here are a few comments from trainees about the types of professional communication and teamwork skills they obtained in the IGERT program:

> Presentations of my research have been given to both a technical and more general audience. As such, I have learned how to target a scientifically knowledgeable, but general audience. Also, the ability to conduct research in teams, which is the norm in industry, has been reinforced in my coursework and mentoring activities.

> Participating in the third semester of the proseminar significantly enhanced my ability to communicate across disciplines and to different audiences. I had to consciously alter my presentation in order to present my research to non-economists and also tailor my comments to others in a similar fashion.

Exhibit 4.10: Trainee Reported Participation in Activities Intended to Develop Professional Skills Applicable to Careers in Industry, Government, or Public Sector

Educational/Professional Activities	Column A Percent (n) of projects whose PI reported activity was used Total N = 33	Column B Number of trainees at projects in Column A	Column C Percent of trainees listed in Column B who reported experiencing the activity
Participation in any research project involving multiple disciplines	100% (33)	305	71%
Participation/experience in team research efforts	88% (29)	260	69%
Training/experience in communications across disciplines and to different audiences (including the general public)	94% (31)	289	48%
Participation in any interaction between academic research and industrial applications or between academic research and public policy development or application	64% (21)	218	42%
Educational interactions (e.g., courses, workshops, seminars) with industry professionals or with government or other public sector professionals	64% (21)	224	37%
Research interactions (other than internships) with industry professionals or with government or other public sector professionals	55% (18)	195	31%

Exhibit reads: The PIs at 100 percent of 33 projects reported that their trainees participate in research projects involving multiple disciplines. There are 305 trainees at these 33 sites, of whom 71 percent reported having participated in a research project involving multiple disciplines.

> The IGERT program in general has enhanced my professional skills by allowing me to learn how to communicate effectively with scientists in other fields; I feel this is critical in industry's team oriented approach to problem solving.

> I had the opportunity to participate on a research project involving people from different backgrounds and areas of expertise. This experience has made me aware of the issues and interests in other areas of study which arise when working on complex problems.

> Working and discussing my ideas in a cross disciplinary environment gave me an understanding of what kind of environment I might encounter after I complete my education. I grew to understand the value of... opinions not in my field. Their insight and approach was much different than my own.

Given that many trainees reported gaining professional skills which they felt would benefit them in non-academic careers, how many trainees had (non-internship) first-hand experience with the industrial or public sector research world? Bearing in mind that many of the trainees were in their first or second year of doctoral study and that subsequent years will probably yield greater levels of participation, roughly one-third of all trainees reported connecting academic research with industrial applications or public policy development and, similarly, about a third reported educational interactions with non-academic professionals. When trainees experienced working with professionals on research projects, they wrote enthusiastically of the benefits of such experiences: "The IGERT program … has been very beneficial to me… [allowing] me to collaborate with sociologists and conduct inter/multidisciplinary research…. This project has greatly enhanced my research ability." Another student was thankful for the opportunity to work in a lab, where s/he met several industrial researchers with whom s/he later collaborated on several research projects. And a third student spent time working with California researchers studying Mayan cave ritual and iconography, an experience which the student attested "broadened my knowledge of my subject and [led to] several papers." Citing the benefits of communication outside one's home institution, a student wrote, "I have talked with and maintained a continuous dialogue with researchers at other institutions, mainly to gain an understanding of their methods and to obtain help in specific areas as applicable to my work."

Trainees' Reports of Off-Campus Internships/Industrial Rotations
Research experience outside the academic setting is an important priority of the IGERT program, and projects are encouraged to promote internships in which trainees can gain research skills and learn to communicate and work with inter/multidisciplinary teams of real-world researchers. Fifty IGERT trainees (16 percent) reported having experienced a total of 54 internships (5 individuals had two internships each), each lasting an average of three and one half months. Roughly half of the internships (48 percent) took place in private industry or business locations. The remainder were split between public sector agencies (20 percent) and public sector laboratories (24 percent). In addition, 2 trainees worked at non-profit corporations.

How did trainees benefit from their internship experiences? Exhibit 4.11 presents trainees' perceptions of the various benefits they received from their internships. Ninety percent of these trainees reported that they gained experience communicating and working with people from different disciplinary or professional backgrounds, a key IGERT programmatic goal. In a similar vein, 65 percent cited experiencing team approaches to problem solving as a benefit. In the words of one trainee:

> Working at the national lab has shown me the importance of working with people from different disciplines. During my time there I worked with chemical engineers, analytical chemists, biologists, microbiologists, organic chemists, biochemists and zoologists. Although

we came from very different backgrounds, we were all working towards similar goals. Being able to draw on the expertise of others from different disciplines not only sped up the research process but broadened my general knowledge of science and expanded my interests.

Another benefit frequently cited by the trainees (82 percent) was an increased awareness of the types of employment opportunities available outside of universities in their own fields of study. Working in an internship, said one trainee, "broadened my [understanding] of an engineer's responsibilities in an industrial environment." Another trainee felt that the internship "showed me that I was versatile and could be successful in any number of industries."

Exhibit 4.11: Trainee Reported Benefits Resulting from Internships

Internship Benefit	Received Benefit from Internship Percent (n=50)
Experience communicating and working with people from different disciplinary or professional backgrounds	90%
Increased awareness of non-academic job opportunities available to people with your education and interests	82%
Experience with applied research	78%
Experience with team approaches to problem solving	65%
Development of a thesis and/or dissertation research topic	41%
Likelihood of a job offer after graduation	37%
Financial or equipment support to complete thesis research	29%
Other benefits	14%

Note: Of the 50 trainees with internships, one reported not experiencing any of the above benefits.
Exhibit reads: 90 percent of trainees with internships reported benefiting from experience communicating and working with people from different backgrounds.

Seventy-eight percent of the trainees with internships felt they gained experience with applied research, and it is this element that appeared most often in the trainee comments, where trainees made frequent references to the technical skills and techniques they acquired as a result of working in the field. Trainees wrote of "increased technical skills," "practicing methods," "applying techniques," and working on "real life problems."

Establishing professional contacts with researchers in the field and understanding how research takes place outside of academic settings were two additional benefits not listed in Exhibit 4.11 which appeared in the trainees' comments. For example, one trainee felt that the two biggest advantages of an internship were "becoming familiar with the industrial working environment" and making industrial connections. In the words of another trainee, the "greatest benefit of my internship experience was that of increased confidence in my own abilities."

International Perspective

Given the increasingly international focus of industry and business and the transition to a global economy, as well as the international nature of the academic research enterprise, IGERT seeks to inculcate familiarity with working across national boundaries by providing trainees with opportunities to work with researchers from other countries. To this end, PIs were asked questions concerning the international opportunities provided for trainees by their IGERT projects. Their responses are presented in Exhibit 4.12.

Exhibit 4.12: International Opportunities Provided for Trainees as Reported by Principal Investigators

Number of projects with trainees = 33
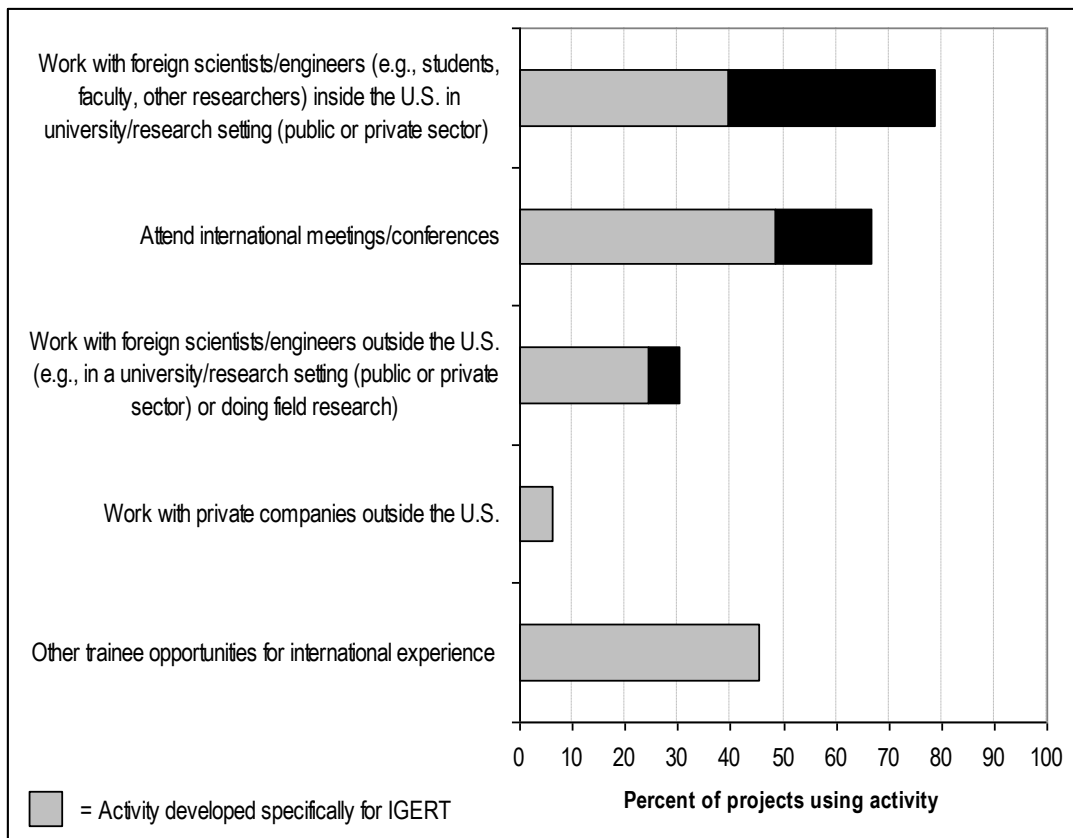
Exhibit reads: Seventy-nine percent of the PIs at projects with trainees report that trainees work with foreign scientists/engineers inside the U.S. in a university/research setting. Fifty percent of these projects (39 percent of the total number of projects) developed this activity specifically for IGERT.

Almost 80 percent of the PIs reported that their IGERT trainees worked with foreign nationals in their own labs or other settings *inside* the United States. IGERT projects without resident foreign scientists often invited foreign researchers to their institutions either as seminar speakers or visiting scholars, and these visits afforded IGERT students the opportunity to meet and interact with researchers from other countries. One project ran its own international conference which all trainees and associates were required to attend. PIs also stressed the importance of daily interactions with international students within their own departments (non-funded project associates) as a means by which trainees gained experience and familiarity in working with individuals from other countries.

Attending international meetings or conferences was the second most common exposure of IGERT trainees to the international research community, occurring at two-thirds (67 percent) of the projects with trainees. PIs reported that trainees attended conferences in various countries, including the United Kingdom, Canada, Japan, and Germany. Some of this travel was subsidized through supplemental international travel grants from NSF. Trainees also participated in brief research internships or research classes at foreign institutions during the summer. These foreign travel opportunities had special meaning for social scientists. "For trainees specializing in the U.S. context," wrote one PI, "the opportunity to take short research trips abroad to flesh out a brief comparative case study can enrich their work significantly."

Less than a third of the projects with trainees offered opportunities for trainees to work with researchers in industrial, university or field research settings *outside of* the United States. Where they existed, these opportunities were almost always created specifically for the IGERT program. PIs wrote of the importance of NSF supplemental funding for international travel and made reference to having applied for such additional funding. Other PIs cited the new status of their IGERT program as explanation for the lack of international opportunities but described plans for expansion along these lines.

Trainees

Trainees were asked a series of questions regarding their exposure to international researchers and research environments. In Exhibit 4.13 trainee responses on two items are presented for those trainees at sites where PIs reported these events took place. Similar to the PIs' comments, most of the trainees' international experiences occurred in the United States. At projects whose PIs reported that trainees had such exposure, 71 percent of the trainees reported that they experienced communicating and working with people of different cultures, nationalities, or backgrounds. Typically, these experiences took place at trainees' home institutions as trainees interacted with students or faculty members of diverse backgrounds. These other individuals could be American citizens with culturally distinct backgrounds as well as individuals visiting from another country. Thirteen percent of trainees reported having worked with international scientists in foreign countries. (Additionally, only 11 percent of *all trainees* reported ever having lived or worked at some time in a foreign country.)

Exhibit 4.13: Trainee Reported Participation in Activities Intended to Develop Trainees' International Perspective

Educational/Professional Activities	Column A Percent (n) of projects whose PI reported activity was used Total N = 33	Column B Number of trainees at projects listed in Column A	Column C Percent of trainees listed in Column B who reported experiencing the activity
Experience working with scientist(s) of other nationalities within the United States	79% (26)	251	71%
Internships or other experience working with scientist(s) of other nationalities, in their own countries	30% (10)	125	13%

Exhibit reads: The PIs at 79 percent of 33 projects reported that trainees at their projects participate in research projects involving multiple disciplines. There are 251 trainees at these 26 sites, of whom 71 percent report having participated in a research project involving multiple disciplines.

Trainees were asked to describe any activities that had "significantly enhanced their understanding of other cultures." In these comments, trainees spoke almost entirely of contacts they had *at their home institutions* with individuals from other countries, whether those individuals were students in their own graduate programs, professors from other countries, or visiting students or faculty from institutions outside the United States. The most frequent form of international contact cited was interaction with other graduate students in their programs who were not funded by IGERT but took the same classes or worked together with IGERT trainees on research projects.

Several students wrote of the benefits of studying with individuals (whether students or faculty members) from other backgrounds. A commonly cited benefit was improved communication skills, whether from presenting materials as a teaching assistant to a class, or from working together in a research laboratory. A number of students reported that they had attended international conferences, either as participants or presenters. Students at one institution even helped organize an international conference in their field at their home institution.

From the trainee comments, it would appear that while many trainees interacted with individuals from a variety of backgrounds and cultures, most of those interactions took place within their home institution or elsewhere within the United States. There is, perhaps, room for expanded support of IGERT trainee travel abroad to further trainees' development of a deeper understanding of academic and industrial research as it takes place in other countries.

Having explored individually the program elements of these 38 beginning IGERT projects, we turn next to PIs' more global assessments of the barriers to implementation they encountered; the elements or events they view as the highlights of their early IGERT experiences; and finally, to the impacts of their projects to date.

Section 5: Implementation Highs and Lows — The Principal Investigators' Overview

Having reported on IGERT project personnel and program elements in some detail, in this section we report PIs' responses to open-ended questions about barriers they have encountered in the implementation of their IGERT projects and, conversely, the highlights of their experiences to date.

Barriers to Implementation

PIs were asked the following question regarding barriers to implementation of their IGERT projects:

> "In the process of implementing your IGERT project, from proposal to working program, what departmental, institutional, or inter-institutional barriers have you encountered?"

While all of the 1998 awardees reported one or more barriers to implementation, 7 of the 21 1999 awardees (33 percent) either left the barrier textbox blank or reported no barriers to date, probable evidence of lack of any substantial implementation in their first year. Exhibit 5.1 displays the general categories of barriers cited by these PIs, and their distribution across the two cohorts.

Exhibit 5.1: Barriers to Implementation Reported by Principal Investigators

	Percent (n)		
Barrier	**1998** **n=17**	**1999** **n=21**	**All** **n=38**
Course coordination, degree requirements, course credit	**59%** (10)	**52%** (11)	**55%** (21)
University culture, politics, or geography	**47%** (8)	**24%** (5)	**34%** (13)
Recruitment	**24%** (4)	**5%** (1)	**13%** (5)
Cost of implementation	**24%** (4)	0	**11%** (4)
Intellectual property issues	**18%** (3)	**5%** (1)	**11%** (4)
Faculty disengagement	**6%** (1)	**14%** (3)	**11%** (4)
No response	0	**33%** (7)	**18%** (7)

The first two categories of barriers listed in the exhibit above, those related to course coordination and to university culture, speak directly to the difficulties of implementing inter/multidisciplinary graduate education within a traditional departmental university culture. The fact that these barriers are much more frequently cited than any others is an indication both of the presence of a strong push toward inter/multidisciplinary culture in these projects, and of the fact that moving from a traditional departmental culture is not an easy task.

The most prevalent concern among these PIs (55 percent) was navigating conflicts in course coordination, degree requirements, assigning credit for team taught courses, or other issues among participating departments or colleges.

At this early stage of the program there have indeed been some barriers that have been encountered.... Developing and teaching new courses, including team-taught courses. [Our] program calls for new courses to be developed, taught, and revised in response to feedback ... Existing management structures (schools, departments) do not readily perceive that they have the flexibility to allocate faculty time to these activities unless sufficient monetary compensation is made available, and even then time is often needed to make necessary adjustments. As a result, there is a distinct danger that the IGERT courses will be undertaken as faculty overloads. Related to this is the problem of assigning credit to team-taught courses wherein one or more of the faculty are contributors from outside of the department or unit where the course is perceived to reside.

While some projects simply cited the credit problem, others said they had found ways to address the issue — one by modifying IGERT course requirements to avoid the conflict, and others by cross-listing the courses in more than one department.

Assignment of teaching credit and, similarly, for students, assignment of course credit for the inter/multidisciplinary proseminar courses has been a minor problem. The difficulty stems from the fact that this program crosses not just departmental lines, but school lines within [the University]. This issue was addressed through a series of conversations with the participating department heads. Ultimately, we received permission to cross-list the course in each of the departments, which solved most of the bureaucratic obstacles.

One 1999 project reported creating a new inter/multidisciplinary Ph.D. program to avoid cross-department conflicts, a "huge task," and then found they still had issues of departmental credit for graduates to deal with because faculty remain associated with traditional departments.

A large concern from the faculty and departmental chairs at the formation of our inter/multidisciplinary program was how the internal reward and recognition system would accept graduation information on [IGERT] students. That is because all [IGERT] students are not part of any traditional department from the administrative systems point of view. The ... graduate program overcame this by reaching agreement with the deans of the colleges affected (Engineering and Arts & Sciences) that the credit for a completed [program] graduate degree would be also "credited" to the department of the student's major professor, as well as to the major professor. In this way, the departments and professors that most strongly support the ... program also receive the majority of the recognition for their support of our successful students.

About a third of the PIs (34 percent across both cohorts) cited university culture, policies, or geography as issues. In spite of the fact that they were asked to discuss *barriers* to implementation, 5 (38 percent) of these reports were positive, praising university support for their inter/multidisciplinary efforts.

Owing to the University's long standing tradition of supporting inter/multidisciplinary research we have experienced very few of the barriers to the IGERT project that are sometimes found in other Institutions. So far we can report no significant institutional problems - indeed, most faculty and administrators are very supportive.

Three PIs, on the other hand, reported such problems as the absence of any university-wide administration, or mismatches between university culture or policies and IGERT inter/multidisciplinary efforts, to be stumbling blocks.

We have proposed to develop some multi-disciplinary courses which are team taught. One barrier to such ideas is to decide how faculty receive teaching credit for these initiatives. All of our faculty members are extremely busy, and teaching an overload is usually not desirable.

Currently, we are proposing short courses instead, but will work with the administration to develop solutions for regular courses.

There has been no experience at running a university wide program .... Previous multi-disciplinary programs were either all in the same college (hence same rules on grants, teaching levels, buyouts, etc. applied) or were joint between two departments with relatively few students. This program is larger, involves more departments, and more colleges. There are no procedures so everything is negotiated and renegotiated as deans, department heads, etc. change. There is no single administrative oversight authority. So no administrator sees this as their responsibility or as directly beneficial to them. The faculty are not given incentives to continue to participate in the program, are not rewarded for participating, and are not given the time away from other teaching obligations to teach in this program.

Three PIs reported university geography itself to be a barrier, citing the physical separation of participating departments or the lack of available common space as barriers to inter/multidisciplinary interactions.

...[B]ecause this is a university wide program there is no common space or gathering area. Faculty and students are spread across 4 buildings, with the classroom of the future in one building and the faculty who need to use it in another, with the administrative staff in a different building .... Being spread so far apart means that the group is not benefiting from the natural synergies of being able to walk down the hall and see each other. It also means that the administrative staff is underutilized. So all meetings are planned. The room offered for the computer lab is in a different building from the students thus decreasing its accessibility and use. Another difficulty is that the relevant computer facilities differ by building/department/college and so we are not achieving any scale advantage or common facility support. This makes it difficult to run common software.

Two other projects, interestingly, fell afoul of university computer systems that could not adapt to their inter/multidisciplinary or cross-college structures.

Four of the 1998 projects cited the unexpected cost of implementing their projects as an issue of concern. Three of these focused on administrative and course costs, while one reported the need to add money to stipends to meet participating department levels of graduate student support.

The greatest difficulties have come from the mismatch of who benefits and who must pay to support the program. Schools (divisions within the university) operate on separate budgets: each is happy to have fellowships funded, but is reluctant to provide support in terms of secretarial services, accounting services, space, equipment, teaching offload, etc. The School of Engineering has been responsive, but the other schools have not.

Stipend support received by our IGERT program has not been sufficient to cover the costs of all student support. This is in part due to the differential graduate student salary levels across colleges and departments. We have decided it is fairer to pay students the prevailing rates of their home department.

Five projects (four of them 1998) cited recruitment difficulties. Two of the 1998 PIs mentioned the citizenship requirement as a barrier, while one other mentioned the relative decline in popularity of their research area of interest (environment) and the loss of potential students to the job market in the "sizzling" economy.

[This] IGERT program presents special difficulties in recruiting qualified students. It is limited to US citizens (who as a group tend to exhibit reduced interest in doctoral education), it is focused largely on engineering and science (in which general interest has been slowly declining nationally), it has an environmental theme (although conceded to be important by all concerned,

including NSF, recent interest in environmental careers has declined), and while [this institution] has developed strong graduate programs over the years, it is a small school still commonly perceived as primarily an "undergraduate" institution for which perceptual (and geographic) barriers exist. We have undertaken a large and ambitious recruiting program the elements of which have been summarized above.

One problem has been the dip in domestic applications due to the sizzling economy. Our limited ability to fund international students (we have to pay $10,000/year non-resident tuition) is temporarily shrinking the size of our program. Will step up domestic recruiting for next year.

One of these projects increased the number of departments in which students could get IGERT-related degrees (from two to twelve) in order to increase the applicant pool and "provide more flexibility for the students." In addition, two PIs (one from each cohort) mentioned the difficulties of recruiting graduate students for their first year when actual IGERT funding does not begin until September.

Our only barrier for this year was that we received the funding so late in the year (September) that we could not recruit new students. Since we felt that the funds should be used primarily to attract new students, we did not feel that we should expend a large amount of funds for students that were already on campus and progressing toward degrees. We did fund three such students mostly to see how things would progress and to enhance their graduate experience. We were also able to concentrate on getting recruitment and other aspects up and going during this year.

Issues resulting from the introduction of internships and other close relationships with industry or national labs were also mentioned by three 1998 projects and one 1999 project. All cited the difficulties of sorting out intellectual property rights. One also mentioned conflicts raised by the differences in the structure of research in universities (longer-term) versus industrial settings (shorter-term).

The ... IGERT calls for significant interactions with industry, including a residency program and ongoing participation of industry personnel in research. Although significant efforts are made to acclimatize both industry and university personnel to the nature of doctoral programs in general and the [IGERT] program specifically, there have been some difficulties encountered. These appear to have two sources: first, different levels of expectations (long term research on an environmental theme is something to which most industries are unaccustomed); and second, the acquisition of data for conducting research (proprietary issues, and the general difficulty of obtaining information from a large complex organization).

Four PIs cited faculty difficulties. Two reported loss of faculty or changes in direction or personnel in major departments since the project was proposed, while two others reported loss of participation among those faculty who had no students receiving IGERT support.

An additional problem for implementation has been the loss of 4 IGERT faculty members, ...[one] will continue to be a co-advisor of one of our trainees ... The other missing faculty will be replaced by new hires. We have offered jobs to [other scientists in these fields] and all indications indicate that they will accept our offers."

One major barrier has been to keep the interest and enthusiasm of the participating faculty up. We have more possible faculty advisors than we have students, and those faculty who do not have a student doing research with them tend not to come to the seminars, etc.

Unique issues included one PI's concern that a policy adjustment made for IGERT trainees could not be extended to other graduate students in the IGERT program (IGERT associates); another's concern that courses created under IGERT would constitute a departmental burden when IGERT funding

ceased; and a third's uncertainty as to how to deal with IGERT students who wanted non-IGERT faculty advisors. (This was allowed as long as the trainees kept an IGERT mentor.)

It is interesting to note that while almost the same percentage of projects in each cohort have faced departmental conflicts about course credits and requirements, a greater proportion of those projects going for two years (the 1998 awardees) are reporting university level barriers and concerns about the costs of implementation, about recruitment, and about the intellectual rights issues raised by internships. These differences are in addition to the lack of response or lack of barriers noted by a third of the 1999 awardees. It seems that the presence of barriers at all, and specifically those barriers cited more frequently by the 1998 PIs, is more likely as projects take on more trainees and move further into their implementation processes. It will be interesting to see, in coming years, whether this pattern of concerns associated with the stage of implementation holds true, and also if new issues will arise as projects move into their third year and beyond.

Project Highlights

In discussing what they consider to be the highlights of this reporting period, more PIs cited individual trainees' inter/multidisciplinary research successes than any other single area of achievement. This was particularly true of the 1998 projects, which have been funded for two years. The 1998 projects also reported more highlights describing project successes and institutional impacts, while the 1999 projects, with only one year of funding, focused more on early implementation successes in recruitment and program development. In this section we note the relative distribution of types of highlights by cohort (displayed in Exhibit 5.2), and then report in greater detail some of the program successes these PIs cited as most outstanding.

Exhibit 5.2: Types of Project Achievements Reported by Principal Investigators, by Cohort

	Percent (n)		
Achievement Area	1998 n = 17	1999 n = 21	All n = 38
Trainees Inter/multidisciplinary Research	47% (8)	24% (5)	34% (13)
Project Features	35% (6)	10% (2)	21% (8)
Institutional Impacts	35% (6)	10% (2)	21% (8)
Program Development	0	29% (6)	16% (6)
Recruitment	0	10% (2)	5% (2)
Social Policy Impacts	6% (1)	5% (1)	5% (2)
No Response	0	14% (3)	8% (3)

Note: Project PIs may report more than one type of achievement/highlight, therefore percents will not add to 100%.

Trainee Inter/multidisciplinary Research

Stories of individual trainees' achievements spoke most frequently to advances they made in research, advances almost always due to the inter/multidisciplinary opportunities made available to them through their IGERT projects.

> The activities of [two of our] students ... exemplify the extraordinary opportunities made possible by the IGERT program. [One] was a first-year student in Physics, and [the other] was a third-year student in Theoretical and Applied Mechanics. Both have interests in biology that fall well outside their fields as traditionally defined. The IGERT program gave them a chance to work together on a mathematical epidemiology project, guided by the PI and by [an] IGERT visiting scholar ... The results of [their] research will be submitted for publication to a mathematical biology journal.

> There are a number of success stories ... But perhaps the most significant is a first year graduate student who has catalyzed a major research initiative involving the Departments of Biology, Manufacturing Engineering, Biomedical Engineering and the Fraunhofer Collaborative for Manufacturing ...for production of a microarray manufacturing facility. As a result of this initiative [the university] has invested $250,000. The project has led to an inter/multidisciplinary grant proposal, and a second is being prepared. It will very likely also lead to the formation of a small business.

> Our student seminar series has been a particularly effective means of enhancing inter/multidisciplinary communication and teamwork... [A] molecular biologist described an algorithm she developed to identify distinct functional domains of a protein. Her idea excited a computer scientist in the course, who was able to write graphics software to map the functional domains onto the protein's crystal structure. A statistics student then developed a way to assess the significance of the program's output. We anticipate a joint publication will result from their combined efforts.

A couple of PIs also added comments from trainees, present or already graduated and in the workforce, to demonstrate the inter/multidisciplinary successes of their projects:

> One of our trainees [had the following comments about our IGERT project]. '[It] is EXACTLY what I was looking for in grad school. ...[The IGERT program] offers a community of people with common interests, and the inter/multidisciplinary nature of the program is a tremendous asset...The "extra" training is a bonus -- like getting a degree plus. I am sure that I am much better read because of the exposure to several disciplines. And I have the confidence to pursue research ideas that might not neatly fit into the disciplines I have the most training in. That is a GREAT feeling - to feel comfortable studying where you want and confident enough to add to the literature in that topic.'

> [Here are some comments from] an e-mail that I received last month from a past IGERT fellow that describes the impact that IGERT had in her career. 'Now that I have been working in the pharmaceutical industry for a while I have really come to appreciate many aspects of the program. .... I just got an award here at work for a project I completed on one our major drug products, and ... my supervisor said I was given this particular project because of my inter/multidisciplinary background. I've found that having a degree at the interface of chemistry and molecular biology is quite impressive in the pharmaceutical industry, and so far I have not met anyone with such a degree. I definitely believe that it helps me stand out in comparison to my peers. I also think that the multicultural aspect of our research group ... has been of great benefit to me as well, and is very important for American students to experience. I notice I'm much more at ease working with colleagues from other countries; particularly in terms of communication.'

Project Features

Program highlights cited by PIs included the unusual (by traditional standards) development of graduate student community, and the participation of trainees in the development of the IGERT project:

> Our first IGERT cohort of thirteen students has just completed their first year in the doctoral program. The most fascinating aspects of this group have been their development of an IGERT student social community, and the initiative the student community has taken in developing self-governance. Even though the students are distributed among five home academic departments, they have developed very close ties with each other, ... fostered by their mutual enrollment in at least one core course during their first semester.... The students have ... shown a great ability to participate in the development of their own academic programs, and to make helpful suggestions to the IGERT administration and to the home academic department administrations.

> The IGERT program has enabled us to accept an excellent group of graduate students who are enthusiastically embracing the program .… [T]hey plan to meet with faculty this summer in developing an inter/multidisciplinary course in astrobiology for incoming students. Inasmuch as there are no textbooks in this subject now, we believe the input of the graduate students may lead to the development of an appropriate textbook in this subject and serve as a model for future programs in this area.

Other program highlights cited by PIs included: specific events, such as international symposia, sponsored by their projects; the benefit of strong international participation at both the faculty and the graduate student level; and the strength of particular aspects of the project (such as internal evaluation or multiple mentoring).

> One of the critical aspects of this program is the multiple mentoring model. This represents an enormous shift in emphasis from a single advisor model to a team-based advising approach... [E]ach graduate student assembl[es] an inter/multidisciplinary team of faculty advisers according to the research needs of their particular project. Students have frequent contact with individual members of their advisory committees, as well as periodic faculty and student team meetings.... The most significant impact of the multiple mentoring model has been to make new ideas and/or approaches more accessible and to facilitate research that transcends disciplinary boundaries.

Institutional Impacts

In some instances PIs described project features whose influence passed beyond the IGERT project itself to influence participating departments or other segments of the university. These features included new practices, new facilities, and the introduction of new courses, initiatives, or programs. Referring to multiple mentoring, for instance, one PI reported:

> We feel so strongly that [multiple mentoring] has a positive impact on our students, that in forming a new department in Biomedical Engineering on our campus, we will require this dual advisor structure for all Ph.D. students.

Several PIs mentioned the development of new facilities that will last beyond the IGERT funding cycle, including a Biophysics Training Laboratory at one institution that "provide[s] students, from diverse disciplinary backgrounds, with state-of-the-art experimental projects from biology coupled with quantitative analysis of data." Another PI reported that an "inter/multidisciplinary photonics

program housed in the Graduate College [has been] created and approved by the university....[and] [l]aboratory courses have been established and will be offered fall semester, 2000."

PIs also pointed to new programs, initiatives, or courses. For example:

> The inter/multidisciplinary emphasis of the program has been institutionalized at the graduate level through the creation of two new ... joint Ph.D. programs: the Ph.D. in Government & Social Policy and the Ph.D. in Sociology & Social Policy. It should be acknowledged that [the university] does not make permanent commitments of this kind lightly. The creation of these doctoral programs required four levels of approval, culminating in a review by the entire Faculty of the Arts and Sciences. The imprimatur of the National Science Foundation IGERT Program was an essential "seal of approval" for our inter/multidisciplinary approach and was therefore critical in assuring the faculty that our program represents the "state of the art." Whereas the IGERT training program serves mainly as an inter/multidisciplinary add-on for existing ... Ph.D. candidates in traditional disciplinary programs, the joint doctoral programs give institutional expression to the role of inter/multidisciplinary scholarship and formally confer a joint doctoral degree.

> The interaction of the NSIDP and Engineering faculty brought about a meeting, and then a collaboration.... This interaction resulted in a new Bioengineering Core ... in the now-funded [university] Udall Center of Excellence in Parkinson's Disease. This is the only Udall Center in the United States which contains a Bioengineering/Neuroengineering Core. The new Udall Center and this collaboration provide exceptional added opportunities for our Neuroengineering trainees, as well as institutional impact.

Social Policy

The influence of some projects reached beyond their institutions to affect social policy in their substantive area:

> The establishment of IGERT "Biosphere Atmosphere Research and Training" has contributed to the initiation of planning for the development of a comprehensive inter/multidisciplinary environmental program for conducting research and education on the aquatic and terrestrial ecosystems of the entire Great Lakes Basin. The program will result in an unprecedented degree of collaboration/cooperation among Great Lakes region universities, NGO's, government agencies and other institutions. The goal will be to substantially improve the scientific understanding of these ecosystems and human impacts on them. This improved understanding will lead to the development of improved policies for managing the ecosystem and human interactions with the ecosystem.

> A particularly successful aspect of the IGERT project is the development of our Sustainable Open Space collaborative initiative. This initiative involves faculty from Geography, Environmental Engineering, Biological Sciences, Urban Planning, and Landscape Architecture, and [a] postdoctoral associate in Biogeography. This group has worked with [trainees] from Urban Planning ... and Geography ... who will soon be joined by [trainees] from History ... and Education ...; four undergraduates have also been involved over two summers.... This group has developed a variety of projects, each building off the other, and all linked to urban open space efforts within Los Angeles. ...[P]reliminary results have informed the city's open space planning recommendations for Council District 13 of Los Angeles, and have drawn the attention of the Councilwoman in that district. Proposals developed on the basis of the program's research will be put forward to the City Planning Commission in July for approval."

Highlights Specific to 1999 Awardees

Project highlights that focused on aspects of program development or recruiting were limited to the 1999 awardees, since these issues are more likely subjects of attention early in a project's implementation. One PI commented on his/her project's implementation of an inter/multidisciplinary doctoral program:

> The [IGERT project's] greatest accomplishment in the first year of its existence has been the definition and implementation of the inter/multidisciplinary ... program as a virtual department in a very conservative university with a very traditional departmental based academic structure. This implementation has been made possible only because many of the faculty in the IGERT associated departments have recognized that a true cultural change in our academic environment will be required to properly prepare our graduates (both [IGERT] and traditional departmental students) for success in the fast moving technology world. Creating the Ph.D. [IGERT project] has given these forward-looking faculty members an on-campus laboratory to examine new educational methods in Ph.D. student preparation, with the idea that successful methods will then migrate into the departmental based Ph.D. programs. The approach we have taken with the Ph.D. [IGERT project] has been recognized as a model program by external educational consultants in a just-completed review of [state] doctoral programs that was chartered by the [State] Department of Higher Education. We feel that this validation will be a significant positive factor in helping us implement the full scope of our educational initiatives planned as part of our IGERT efforts.

Two PIs focused on recruiting successes, and made clear that inter/multidisciplinary graduate programs are gaining favor among applicants:

> Our biggest highlight came from our applications. We were pleased with the number of excellent students who applied to our program and the number who chose to come next year. Many of the applicants indicated that this mixture of Neurobiology, Behavior, Robotics, Modeling and Neuroprothetic work was exactly what they had been looking for. Thus, we anticipate continued success in our recruitment.

Another PI provided several pointers, reporting that potential trainees are attracted to "the extra initiatives we offer outside the usual graduate program. The teamwork approach, the hardware/analytical mix of projects, and the multi-disciplinary emphasis are especially attractive to them." S/he added that "[t]he internship program is very attractive to students," and finally, that they "are working to institutionalize this approach for graduate student recruitment across the universities. We frequently take a haphazard approach to identifying and attracting graduate students, and this program will provide a structure on which to base future recruiting efforts."

Summary

In surveying this set of project highlights, it is impressive that PIs have so much to report, of such magnitude, and so early in their projects' development. The presence of the inter/multidisciplinary mode of addressing graduate education and research appears to be universal, in practice as well as in word. This theme was also prominent in the Barriers to Implementation section, and its presence, both positive and negative, speaks to the centrality of the inter/multidisciplinary approach in the minds of these PIs. Also surprising and impressive is the number of reported impacts on participating departments, on institutions, and on relevant social policy. It will remain for site visits and further web data collections to determine the sources of the early effectiveness of many of these projects. Questions arise such as: Did the awards fall to particularly well-prepared departments/programs? Does the large number of trainees supported each year increase the impact of the project on

participating departments and institutions? Is the very clearly stated inter/multidisciplinary research theme one that both attracts and stimulates greater synergies? Which of those, if any, and what other elements play a part in these early successes?

Section 6: Impacts of the IGERT Program

What impact has the IGERT program had on participating institutions, their curricula and faculty members? Are there plans to permanently alter institutional landscapes as a result of IGERT project developments? This section of the report documents PI-reported impacts of their projects on institutional course offerings, program requirements, and faculty members. It also asks to what extent projects have responded to the self-evaluation, and whether or not steps have been taken towards institutionalization of IGERT project elements into the institutional body at large.

Course Offerings and Requirements

The development of new courses, workshops seminars, and requirements is one of the more immediately evident and tangible impacts of the IGERT program, thus it is not surprising that 32 of the 33 projects with trainees report at least one development along these lines. Exhibit 6.1 reveals that the most popular forms of new offerings were new inter/multidisciplinary courses serving the research area and new seminar series, workshops, and/or conferences, some combination of which have occurred at 85 percent of the project sites.

Exhibit 6.1: Types of Institutional Impacts During the Reporting Period as Reported by Principal Investigators*

Type of Institutional Impact	Percent (n) of Projects Developing Impact	Average number of impact type**
New inter/multidisciplinary offerings resulting from the IGERT project developed to serve the research area	**85%** (28)	2.61
New seminar series, workshops, and/or conferences resulting from the IGERT project grant	**85%** (28)	2.57
New courses developed by the IGERT project to serve the research area	**82%** (27)	2.89
New course requirements resulting from the IGERT project required for a trainee to complete the doctorate in the research area	**67%** (22)	2.86
Other	**36%** (12)	1.50

*   Project n=33
** The average number of impact type is calculated separately for each type of impact for the group of projects who reported experiencing that type of impact.
Exhibit reads: Twenty-eight projects (85 percent) developed new inter/multidisciplinary offerings. Across projects where such offerings were developed, the mean number of offerings was 2.61.

Workshops, whether open to IGERT members or larger audiences, provided projects with an opportunity to instruct trainees while exposing them to individuals and research from multiple disciplines. IGERT projects offered workshops on research ethics, research based inter/multidisciplinary education, bioinformatics, and skills needed to survive in graduate school. Some brought in speakers from outside the institution to address IGERT trainees; others provided a forum in which trainees could present their research.

Some IGERT projects offered weekly seminars aimed specifically at IGERT trainees. A weekly seminar series at one IGERT project was open to the public but addressed issues of concern to the IGERT trainees, who attended regularly. Another institution developed a seminar series that "not only crosse[d] disciplines [but also] institutions via teleconferencing," presenting information to students and faculty at four other colleges. Describing the nature of this kind of workshop, a PI wrote:

> These workshops are designed to provide … students with a broader perspective of their field by synthesizing and applying the knowledge and skills they have developed and to view their own work in a larger global, scientific context. The workshops also aim to expose students to, and increase their appreciation for, international scientific efforts and non-academic issues in regard to biosphere-atmosphere issues.

A third popular impact of IGERT at participating institutions was the development of new courses serving the research area, occurring at 82 percent of the project sites. Projects developed an average of nearly three new courses. These courses covered a wide range of topics, from technology to research ethics to theory, and tended to fall into two categories: (1) courses dealing with defined disciplinary topics, and (2) courses about the IGERT experience. The latter tended to be small seminars developed exclusively for IGERT trainees and taught by teams of faculty spanning multiple disciplines. Benefits of offering a seminar required for all trainees were explained by one PI:

> The proseminar sequence promotes the IGERT goals because it serves as the central inter/multidisciplinary training vehicle for our trainees. The course explores the causes and consequences of inequality from different disciplinary perspectives, it draws in numerous program faculty members from the different participating disciplines as instructors, and it brings together the trainees from different disciplinary backgrounds.

Courses focused on specific disciplinary topics utilized the project's inter/multidisciplinary framework, and might or might not have be restricted to IGERT trainees. At one project, a course presenting an "inter/multidisciplinary approach to systems analysis techniques" was developed which was the "only engineering systems course offered" in participating departments, and proved "to be popular among non-IGERT graduate students and undergraduate students" in addition to being a requirement for IGERT trainees. At another institution, a technology course developed by the IGERT project filled an important gap in the institution's curriculum by instructing non-engineers on the basics of certain program-specific technologies.

The development of new courses is likely to have a lasting impact; in university settings where traditionally curricula are slow to change, chances are that new courses developed with inter/multidisciplinary themes in mind will linger long after the IGERT funding has disappeared.

Finally, roughly two-thirds (67 percent) of IGERT projects instituted new course requirements for trainees. While these changes are not, in and of themselves, institutional changes, they are steps towards the development of what could become a recognized inter/multidisciplinary program. The most frequent of these requirements was attendance at the weekly IGERT seminars described above. Other requirements included taking specific courses or taking a prescribed number of courses from a designated inter/multidisciplinary course list. For example, trainees at one project "must take two courses from each of the two other participating departments from a selected group of relevant courses." The goal of one project's requirements was to provide students with a "solid, multi-

disciplinary experience," while another strove to develop in trainees "both breadth and depth in an inter/multidisciplinary focus field."

Impact on the Faculty

Faculty are an institution's backbone. Some would argue it is impossible to effect change without modifying faculty perceptions and behaviors. So it is encouraging to receive reports from the majority of PIs that there have been changes in the faculty as a result of the IGERT program. These reports are described in Exhibit 6.2.

Exhibit 6.2: Impacts of IGERT on Faculty Activities as Reported by Principal Investigators*

Impacts on Faculty	Percent of Projects (n)
Sharing mentorship of students across disciplines more often	**85%** (28)
Participating on inter/multidisciplinary dissertation committees more often	**76%** (25)
Teaching new courses that cross traditional disciplinary boundaries	**73%** (24)
Increased participation in non-home-discipline meetings, conferences, etc.	**61%** (20)
Jointly authoring papers across disciplines more often	**55%** (18)
Team-teaching courses across disciplines more often	**52%** (17)
Members of inter/multidisciplinary teams winning new grant support more often	**52%** (17)
Using new pedagogical approaches	**24%** (8)
Other faculty activities indicative of growth stimulated by participation in the IGERT project	**21%** (7)

* Project n=33

Exhibit reads: Faculty are sharing mentorship of students across disciplines more often than before in 85 percent of the projects with trainees.

The IGERT project appears to be bringing faculty closer together, since at 85 percent of the projects with trainees faculty were more often sharing mentorship of students across disciplines, and at 76 percent of the projects faculty participated more often on inter/multidisciplinary dissertation committees. Encouraging trainees to adapt multidiscipinary research work patterns appears also to have affected the students' advisors and mentors in the faculty at large. "This mentoring of students," wrote one PI, "is allowing the professors to learn more about research methods outside their home disciplines while the students are benefiting from a professor's view from a different perspective than they usually experience." Teams of faculty often helped guide an IGERT trainee's research projects. This joint mentorship at one project "broadened the inter/multidisciplinary activity of all our faculty and has generated new project ideas currently under development." The student-focused aspect of the mentoring system was elaborated on by one PI:

One aspect of [the mentoring system's] implementation that is worth noting is how student-driven it has turned out to be. As IGERT students begin to define their research topics, they are encouraged, and are not hesitant, to seek out needed expertise among the faculty at large. Some faculty are thus far content to act in an advisory capacity while others have more enthusiastically embraced the concept.

In keeping with the PI reports of new course development, it is not surprising that 73 percent of the projects reported their faculty were teaching new courses that cross traditional disciplinary boundaries. Faculty appeared to be crossing disciplinary boundaries on multiple fronts, whether by attending out-of-discipline meetings (61 percent), jointly authoring papers with faculty from other disciplines (55 percent), team-teaching courses across disciplines (52 percent), or winning grant support as members of inter/multidisciplinary teams (also 52 percent). The increase in inter/multidisciplinary partnerships after two years of IGERT funding is highly encouraging and is likely to continue as the projects mature.[13]

Institutionalization of IGERT Features

In providing IGERT funding to institutions, NSF aims not just to support graduate students for five years but to catalyze a change in the way science and engineering graduate students are trained. As such, NSF hopes that elements of the IGERT program will be institutionalized as permanent features of home departments or new, inter/multidisciplinary programs. To assess whether or not this process has begun, PIs were asked to identify which project features had been institutionalized; their responses are presented in Exhibit 6.3.

It would appear that IGERT has already met with some success in effecting lasting change in the way graduate programs are structured. Fifty-eight percent of the PIs reported that their departments have adopted new paradigms for integrating research and education at the graduate level. About half (48 percent) had reduced barriers to inter/multidisciplinary education and research. New entrance requirements were adopted by approximately one-third (36 percent) of the projects. Once again, this degree of progress is especially encouraging given that these projects are only one or two years into their five-year funding period. One would expect that the numbers of projects institutionalizing IGERT program elements will increase with time. It is interesting that the change least often reported, new paradigms for graduate student assessment or advancement to candidacy, lies in the area most firmly controlled by traditional department policies.

All IGERT PIs reported that they plan to maintain some or all of the IGERT project beyond its five-year funding period, and all but five had already taken various steps towards this goal. Over two-thirds (70 percent) of the projects had made plans to continue IGERT initiatives, concepts, and collaborations beyond the funding period; another two-thirds had worked with the administration and/or funding sources at their institution to plan for alternate program support after five years. In addition, just under one-third of the projects had written a plan outlining the continuation of IGERT projects. The nature of this process varied across the institutions, with some schools establishing actual committees aimed at institutionalizing inter/multidisciplinary educational and research initiatives, while other schools had only experienced an informal shift in departmental thinking. Overall, considering the early nature of these projects, such forward-thinking momentum is encouraging.

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[13]   It should be noted that a PI's indication that a certain impact has taken place reflects only that there has been an *increase* in a given type of behavior, not necessarily that all faculty have changed their patterns.

Exhibit 6.3: Institutionalization of IGERT Features as Reported by Principal Investigators

Project Feature	Institutionalized Percent (n)
New paradigms for integrating research and education at the graduate level	**58%** (19)
New methodologies that reduce barriers to inter/multidisciplinary education and research	**48%** (16)
New entrance requirements	**36%** (12)
New paradigms for graduate student assessment or advancement to candidacy	**24%** (8)
Other	**58%** (19)

Exhibit reads: New paradigms for integrating research and education at the graduate level were institutionalized in 19 (58 percent) of the IGERT projects.

Impact of the IGERT Self-Assessment Process

The IGERT Performance Assessment requires that projects tie goals and objectives to indicators and specific measurements for assessing progress towards achievement of project goals. PIs were thus asked whether they had made any changes in their IGERT project as a result of the self-assessment procedure, to which 24 (73 percent) responded they had. Examples of these changes included:

- Altering the admissions process so that students were not rejected until all possibly appropriate departments had examined the applicant,

- Creating a common degree title across the units for all IGERT graduates,

- Modifying seminar topics,

- Increasing the program's visibility to minority applicants through recruitment and publicity,

- Ensuring that all graduate committees were inter/multidisciplinary in membership,

- Restructuring the lab rotation portion of the program,

- Adding personal interviews to the admissions process,

- Instituting a mentoring program where current IGERT trainees mentor future IGERT awardees,

- Improving the first year seminar course along curricular and organizational dimensions, and

- Expanding internship opportunities for trainees.

Many PIs noted that while specific changes have been made, they are in the early stages of the grant and either have not yet undergone a self-assessment or have not yet been able to fully implement the desired changes. PIs described their projects as "works in progress" and offered hopeful plans for the future.

Appendix A: Inter/multidisciplinary Themes

Each IGERT project organizes faculty, curricula and students from several different traditional academic disciplines around a central inter/multidisciplinary theme. Because these themes range across NSF directorate boundaries, broad subject area panels were developed to consider IGERT proposals: life science and engineering and computation, physical science and engineering and computation, environmental science and engineering and computation, and human science and engineering and computation. Exhibit A.1 presents the 38 IGERT projects awarded in 1998 or 1999 according to their cohort year and inter/multidisciplinary theme, within these broad focus areas.

Exhibit A.1: Project Distribution By Cohort, Focus Area, and Inter/multidisciplinary Theme

Broad Focus Area
    Inter/multidisciplinary Theme

Life Science and Engineering and Computation
1998 Cohort
    Astrobiology
    Integrative graduate training of neuroscientists and computational/physical scientists
    Optical molecular bio-engineering
    Research and training at the interface of biology, mathematics, and physics

1999 Cohort
    Bioinformatics and computational biology
    Complex biological systems
    Computational neuroscience
    Evolution of development
    Neuromechanics
    Freshwater sciences in contrasting climates
    Microbial biogeochemistry
    Neuroengineering
    Therapeutic and diagnostic devices

Human Science and Engineering and Computation
1998 Cohort
    Geographic information science
    Inequality & social policy
    Learning and action in the face of uncertainty
    Transportation technology & policy

1999 Cohort
    Cognitive science of language
    Computational social & organizational science (CS/ECE and sociology/organizations/social networks)
    Global manufacturing logistics
    Integrative information, computer and computational sciences

Environmental Science and Engineering and Computation
1998 Cohort
    Environmental manufacturing management
    Lakes and society
    Urban sustainability

1999 Cohort
    Biosphere-atmosphere

(Exhibit A.1 cont.)

Broad Focus Area

Inter/multidisciplinary Theme

Multiphase environmental transport
Nanophases in the environment, agriculture, and technology

Physical Science and Engineering and Computation

1998 Cohort

Bioinformatics
Photonics
Integrated sensing architectures
Smart sensors and integrated devices
Nonlinear systems
Optical science and engineering

1999 Cohort

A new era in electronics education (physics, EE, ChE, ME are primary departmental participants)
Variable speed electromechanical drive systems
Molecularly designed electronic, photonic, and nanostructured materials.
Nanostructural materials and devices
Science and engineering of laser interactions with matter

Appendix B: Consortial Arrangements

Consortial arrangements, formal alliances between an IGERT project and at least one other organization, are designed to help IGERT programs achieve objectives (e.g., recruit minority students, provide graduate students with education in a specific field) that might not otherwise be accomplished. These arrangements can take multiple forms: partnerships with non-Ph.D. granting institutions in order to recruit undergraduate students; partnerships with Ph.D. granting institutions to afford IGERT trainees more research and educational opportunities; and partnerships with institutions or organizations that are specifically geared towards increasing the number of women, under-represented minorities, and/or disabled persons in doctoral programs. The partnership can assume any number of forms, with IGERT and partner institutions sharing laboratories, libraries and other facilities, working together at either site, and collaborating on research or teaching enterprises.

Consortial Partners

Seventeen (52 percent) of the 33 IGERT projects with trainees reported having consortial arrangements. These 17 projects collectively claimed 44 consortial arrangements; however, only 36 of these, housed in 14 projects, were active during the reporting period. Surprisingly, all but 4 of these active arrangements belonged to institutions in the 1999 cohort. The arrangements were with a variety of organizations as shown in Exhibit B.1. More than 70 percent of projects with consortial alliances have arrangements with other educational or research institutions, offering trainees opportunities for collaborative research, education, and teaching opportunities. A much smaller percentage of projects have relationships with private corporations, foreign governments, or federal laboratories.

Exhibit B.1: Distribution of Active Consortial Arrangements across Partner Type

Partner Type	Percent (n) of projects having consortial arrangements with this partner type Project n = 14	Total number of consortial arrangements with this partner type Arrangement n = 36
Institutions	**71%** (10)	16
Corporations	**29%** (4)	7
Federal Laboratories	**21%** (3)	4
State or Local Governments	**14%** (2)	3
Foreign Governments	**7%** (1)	5
Federal Agencies	**7%** (1)	1

Note: Percentages do not sum to 100% because projects have multiple consortial partners.

Consortial Exchanges

PIs were asked to identify the nature of exchanges occurring in each of their consortial arrangements. The possibilities offered were:

- **Collaborative research/teaching**: partner organization's staff work with IGERT project staff on collaborative research or teaching.

- **Personnel exchange**: project staff and/or partner organization staff using each other's facilities or working at each other's sites.

- **Facilities**: use of the partner organization's facilities for project IGERT activities.

The most commonly reported exchange, occurring, either singly or in combination with other exchanges, was collaborative research or teaching, followed by personnel exchange, and then facilities. Notice that most consortial arrangements encompassed two or more types of exchange (Exhibit B.2). In fact, those combining all three types of exchange were most common, and occurred in 57 percent of these projects. The second most common combinations of exchanges included collaborative research/teaching and personnel exchanges, and collaborative research/teaching alone (29 percent of projects, in each case). These three combinations of exchange were those seen most commonly in consortial arrangements with other institutions.

Exhibit B.2: Distribution of Active Consortial Arrangements across Exchange Activity

Exchange Activity	Percent (n) of projects using this exchange activity Project n = 14	Total number of exchange activities of this type Arrangement n = 36
Combination of facilities, collaborative research/teaching, personnel exchange	**57%** (8)	13
Combination of collaborative research/teaching and personnel exchange	**29%** (4)	8
Collaborative research/teaching	**29%** (4)	7
Combination of facilities and collaborative research/teaching	**14%** (2)	2
Personnel exchange	**14%** (2)	4
Facilities	**7%** (1)	2

Note: Percentages do not sum to 100% because projects have multiple types of consortial exchanges.

Consortial Types

PI were also asked whether their consortial arrangement was intended to increase underrepresented minority involvement in their project, and whether it was with a Ph.D.-granting or a non-graduate degree granting entity. The distribution of consortial arrangements across these arrangement types is

shown in Exhibit B.3. Consortial arrangements with non-degree granting entities, such as corporations, federal labs, and non-graduate degree granting educational or research institutions, and arrangements with doctoral degree granting institutions were most common. Arrangements intended to increase minority participation, whether with degree granting or non-degree granting entities, were reported by only 5 (36 percent) of the projects with active consortia.

Exhibit B.3: Distribution of Active Consortial Arrangements across Arrangement Type

Arrangement Type	Percent (n) of projects having these consortial arrangements Project n = 14	Total number of consortial arrangements of this type Arrangement n = 36
Non-degree granting entity	**57%** (8)	16
Ph.D. granting institution	**57%** (8)	14
Minority enhancing	**14%** (2)	3
Minority enhancing and Ph.D. granting	**14%** (2)	2
Minority enhancing and Non-degree granting	**7%** (1)	1

Note: Percentages do not sum to 100% because projects have multiple consortial arrangement types.

PI Comments
Describing the benefits of consortial arrangements in the accompanying survey textbox, PIs often wrote about the opportunities for trainees to experience different research environments. Trainees gained an appreciation of the "industrial perspective on basic research," worked with institutions that "apply basic research in precision measurement methodologies to interdisciplinary problems with an industrial impact," experienced "research driven to a significant extent by potential industrial applications," and became aware of research projects different from their own. Another objective was to foster self-sufficiency:

> One of the goals of the IGERT program is to develop the entrepreneurial skills of our graduates that would allow them to successfully start new companies based on local research. This collaborative effort is acting as a demonstration case of a formal relationship between the University and a successful technology startup company to encourage its expansion. It also provides a real example of a local entrepreneurial startup by a Ph.D. graduate of this campus directly based on his Ph.D. research.

Still another benefit was the expansion of IGERT concepts and opportunities to students outside the IGERT trainee population: "Our collaboration with [another university] enables a much larger spectrum of students (i.e., those that do not necessarily satisfy the IGERT requirements) to participate and benefit from the developed IGERT initiatives." And finally, consortial arrangements with other institutions (especially non Ph.D. granting ones) could yield potential future IGERT trainees, with IGERT faculty and trainees working on research projects with undergraduates, who learn advanced research techniques and are encouraged by the IGERT affiliates to consider further graduate studies and apply for IGERT Fellowships.

Appendix C: Additional Funding Sources

While there are no cost sharing requirements for IGERT projects, a number of projects, nonetheless, used the receipt of the grant to leverage other funds for their research areas. In the web survey, PIs were asked to report additional funding sources, either direct dollar donations or estimated value of in-kind funding.

Funding Sources

Although 20 projects (53 percent) reported receiving no additional funds, 18 IGERT projects (10 from the 1998 cohort; 8 from 1999) did receive additional funding sources. Together, these 18 projects reported a total of 84 sources, an average of 4.5 per project. However, most of the additional funds (64 percent) were received by just five projects, while nine projects reported one source only. Thus, these findings should be interpreted with caution.

Exhibit C.1 shows the donors of additional funds in order of the proportion of projects reporting funds from these sources.

Exhibit C.1: Distribution of Additional Funding Sources across Donor and Donation Types

Donor Type	Percent (n) of projects receiving funds from this source project n = 18	Total number of direct donations from this source	Total number of in-kind donations from this source
Institutions	**61%** (11)	26	4
State or Local Governments	**33%** (6)	11	1
Corporations	**28%** (65	9	0
Federal Agencies	**22%** (4)	11	0
Foundations and other non-profits	**17%** (3)	4	0
National Science Foundation	**17%** (3)	4	0
Federal Laboratories	**6%** (1)	3	2
Other	**22%** (4)	9	0
TOTAL		77	7

Note: Percentage of projects receiving funds from these sources exceeds 100% because a number of projects received funds from more than one source. All of the in-kind donations came from donors who also provided direct support, except in the case of two federal laboratories which provided in-kind support only.

Exhibit reads: 61 percent of the 18 projects receiving any additional funds received additional funding from institutions. Overall, institutions provided a total of 26 individual direct dollar grants and 4 in-kind donations to the 11 projects to whom they provided funding.

Dollar Amounts and Uses of Additional Funding

By Donor: Dollar amounts of donations from the 76 additional funding sources providing direct dollar funding to the projects[14] ranged from $550 to $980,000, with a median of $30,000, and the middle 50 percent receiving between $12,600 and $61,000. As shown in Exhibit C.2, NSF provided the largest median donation, with state and local governments and federal laboratories following. The six reported in-kind donations ranged from $12,000 to $350,000, and averaged $124,380, with a median value of $69,825.

Exhibit C.2: Distribution of Additional Funding Amounts across Donor and Donation Types

Donor Type	Median Dollar Amount of Direct Donations from this source (n) source n = 76	Direct Donations Range	Estimated Median Dollar Value of In-Kind Donations from this source source n = 6	In-Kind Donations Range
Institutions	**$36,200** (25)	$9,000-$168,000	**$99,651** (3)	$40,000-$222,629
State or Local Governments	**$50,000** (11)	$20,000-$302,000	**$350,000** (1)	n/a
Corporations	**$25,000** (9)	$10,000-$200,000	0	n/a
Federal Agencies	**$14,000** (11)	$2,000-$138,000	0	n/a
Foundations and other non-profits	**$16,850** (4)	$11,300-$980,000	0	n/a
National Science Foundation	**$87,445** (4)	$13,000-$218,000	0	n/a
Federal Laboratories	**$43,500** (3)	$7,000-$89,000	**$17,000** (2)	$12,000-$22,000
Other	**$10,000** (9)	$550-$60,000	0	n/a

By Project: The median amount of direct funding received from all sources by the 17 reporting projects[14] was $200,000, with a range of just below $18,000 to slightly over $1,000,000; the middle 50 percent of the projects received between $60,000 and $486,000. The six projects providing information on in-kind sums reported a median of almost $70,000, with a range of $22,000 to $222,600.

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[14] One project inserted the value of $1 for all funds received because their university preferred that they not supply unofficial estimates. That project has been left out of all calculations in this section.

The median number of donor types providing funding to any one project was two, with almost half of the projects reporting only one donor type. At the other extreme, two of the projects received donations from six different types of donors.

As shown in Exhibit C.3, the largest amounts given to individual projects, summing all individual donations from a particular donor type, are also from foundations, with federal labs and state and local governments close together in second place.

Exhibit C.3: Distribution of Total Additional Funding Amounts to Individual Projects Summed across Donor and Donation Types

Donor Type	Median Dollar Amount of Total Direct Donations from this source (n) n = 36	Total Direct Donations per Project Range	Estimated Median Dollar Value of In-Kind Donations from this source n = 7	Total In-Kind Donations per Project Range
Institutions	$50,000 (10)	$17,920-$284,012	$99,651 (3)	$40,000-$222,629
State or Local Governments	$137,500 (6)	$25,000-$485,000	$350,000 (1)	n/a
Corporations	$64,830 (5)	$11,000-$200,000	0	n/a
Federal Agencies	$110,850 (4)	$16,000-$195,200	0	n/a
Foundations and other non-profits	$33,700 (3)	$11,300-$980,000	0	n/a
National Science Foundation	$99,890 (3)	$88,000-$218,000	0	n/a
Federal Laboratories	$139,500 (1)	n/a	$17,000 (2)	$12,000-$22,000
Other	$36,750 (4)	$550-$115,000	0	n/a

Examining these sources of funding from one of the four projects with more than eight donors may give some sense of the potential scope and range of projects' activities. This project, whose focus was urban sustainability, listed 12 sources of additional funding totaling approximately $508,000, with individual sources ranging from $2,000 to close to $170,000. Funding sources for this project included one corporation, two different federal agencies, two foundations, and seven other funding sources, four of which were associated with the project's home institution. The funds supported the following activities: specific studies or collaborative projects that were a part of the IGERT project; faculty cross-departmental interactions; travel associated with international project activities in Mexico and in France; summer support for trainees; support of involved undergraduate students, and such activities as preparation of brochures supporting collaborative projects and public education associated with the projects. In these last two instances, a brochure was developed for architects and

developers on storm water pollution prevention, and trainees visited high schools to teach students about urban sustainability and promote an urban sustainability poster contest.

In addition to the uses of additional funding mentioned above, other projects reported infrastructure support; supplies, equipment, and facilities; salaries for support staff and trainee mentors; community-building activities for project participants; recruiting support; technical support; tuition scholarships for trainees; and funding of non-IGERT-eligible students (IGERT associates). In one case, a corporation provided $200,000 to support six research projects that were awarded to faculty through a competitive process requiring participation of interdisciplinary teams. In another, the National Center for Atmospheric Research provided a project time on the Cray Super Computer, making it possible for the trainees to have access to state-of-the-art modeling tools.

While it is not possible to determine whether these funding associations preceded, or were instigated by, IGERT funding, it is clear that they provided additional opportunities to those projects having them.

Appendix D: Survey Instrument

Attached.

Principal Investigator Survey Instrument

Project Personnel

- Principal Investigator Data

- Co-PI or Trainee/Associate Advisor Data

Assessment of Trainee Quality and Project Success

Project Features

- Recruitment Strategies

- Admissions Criteria

- Inter/multidisciplinary Training

- Trainee Preparation in Communication and Teamwork

- Trainee Preparation to Conduct High-Quality Research

- Trainee Preparation for Careers in Industry, Government, or Public Sector

- Trainee Preparation for Faculty Positions

- International Opportunities

- Other Structural Arrangements

Consortial Arrangements

Additional Funding

Impacts

- Institutional Impacts and Assessment
- Impacts on New Offerings, Requirements
- Impacts on Institutionalization
- Impacts on Faculty

Assessment

Project Characteristics, Highlights and Other Information

Trainee Survey Instrument

- Trainee Data

- Academic/Professional Background prior to IGERT Association

- Academic Achievement

- Ability to Communicate Professionally

- Professional Skills to Conduct High-Quality Research

- Professional Skills in Education

- Professional Skills Applicable to Careers in Industry, Government, or Public Sector

- Off-Campus Internships/Industrial Rotations

- International Perspective

- Breadth and Depth of Knowledge

- Mentoring and Special Assistance