Essential Competencies for Interdisciplinary Graduate Training in IGERT

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Executive Summary

The Integrative Graduate Education and Research Traineeship (IGERT) program represents a substantial investment by the National Science Foundation (NSF) to improve the quality of graduate education, and ultimately, to increase the number of graduates better prepared to address the nation's 21st century scientific and technological needs. The current study focuses on the program's goal of educating Ph.D.-level scientists to develop the depth and breadth of knowledge and skills to become leaders in their respective fields; it does so by exploring how IGERT grantees are conceptualizing and delivering interdisciplinary doctoral training.

Program Background

The IGERT program supports interdisciplinary research that draws purposefully from different disciplinary approaches to the research enterprise as well as from emerging issues the scientific community has had neither the knowledge base nor technology to address. IGERT provides grants to institutions of higher education to support research and Ph.D. training of U.S. citizens or permanent residents in science, technology, engineering, and mathematics (STEM) fields. Funded IGERT projects offer their graduate trainees financial support as well as a wide range of interdisciplinary research and educational enrichment experiences. Most IGERT projects are led by a Principal Investigator (PI) in a single discipline, often in partnership with other co-PIs from collaborating departments or institutions. The projects' PIs design a set of educational and training activities that include interdisciplinary courses and seminars, cross-department laboratory experiences, team-based research projects, and off-campus internships, among other activities. The program further emphasizes the preparation of skilled graduates who can communicate complex ideas to laypersons and work well in team settings.

The Current Study

The purpose of this study is to deepen NSF's understanding and broaden general knowledge of how IGERT grantee institutions prepare Ph.D. students to conduct interdisciplinary research. Based on an in-depth literature review, and in close consultation with NSF and the study's advisory committee, the Abt study team identified six core competencies characterized as essential for conducting interdisciplinary research:

1. Ability to develop depth of knowledge in one discipline or field of study
2. Ability to recognize the strengths and weaknesses of multiple disciplines
3. Ability to apply the approaches and tools from multiple disciplines to address a research problem
4. Ability to work in a team with individuals trained in different disciplines
5. Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines
6. Ability to communicate about interdisciplinary research to non-academic audiences (laypersons)

This set of competencies represent a starting point for understanding whether IGERT participants perceive this set as important for conducting interdisciplinary research; and if so, how IGERT projects develop trainees in the six areas. The study's key research questions are targeted explicitly on whether and how this group of competencies is applicable to IGERT projects. Specifically,

1. Whether and in what ways do IGERT participants (PIs and trainees) perceive the knowledge, skills or abilities drawn from the literature as important to conducting interdisciplinary research?

2. What activities do projects implement to develop trainees' interdisciplinary research capacity, as characterized by these knowledge, skills or abilities? How do projects assess trainees' development as interdisciplinary scientists?
3. How helpful do trainees perceive their IGERT training to be in developing their capacity to conduct interdisciplinary research as characterized by these six areas?
4. How confident are IGERT trainees of their knowledge, skills, and abilities in these six areas?
5. What challenges do trainees encounter with the IGERT traineeship?

In addition, PIs were asked what they look for in prospective trainees, and both PIs and trainees were asked about other competencies important to interdisciplinary research. The study team also asked PIs about successful and challenging aspects of their IGERT projects.

These questions were addressed through data collected directly from two key respondent groups: IGERT PIs and trainees from a set of 40 IGERT projects initially funded in 2007 and 2008. Data come from interviews with 39 of the 40 project PIs and from 431 trainees across the 40 projects. The study describes how IGERT projects are designed, from the PI perspective, and how they are experienced, from the trainee perspective, to inform an understanding of whether the skills presented in the research literature are in fact important to IGERT PIs and trainees.

Major Findings

The study's findings show that the six skill areas suggested by research evidence as critical to conduct interdisciplinary research were described by both PIs and trainees as the primary skills they believe are important.

- Both PIs and trainees rated the six interdisciplinary competencies quite similarly; a substantial majority (85 percent or more) of both groups characterized four of six competency areas as important or very important.
- The two competency areas rated as important or very important by the largest number of PIs and trainees were the ability to communicate research in one discipline to researchers trained in others (95 and 99 percent of PIs and trainees, respectively), and the capacity to work in a team setting with researchers from other disciplines (92 and 98 percent of PIs and trainees, respectively).
- An overwhelming majority of trainees (99 percent) and PIs (87 percent) indicated that the ability to understand both contributions and limitations of different disciplines, and the capacity to apply multidisciplinary approaches and tools (86 percent of PIs and 96 percent of trainees) were essential in an interdisciplinary research setting.
- Slightly fewer respondents, though still a large majority, of both PIs and trainees rated substantial depth of knowledge in one discipline and the ability to communicate interdisciplinary research to non-academic audiences as important or very important for conducting interdisciplinary research (89 and 70 percent, and 73 and 85 percent, respectively, for PIs and trainees).
- PIs reported that they look for specific qualities and experiences in prospective IGERT trainees, including a strong academic background, interest and commitment to interdisciplinary research, prior research experience, and a flexible approach towards academic research.
- According to PIs, assessment of trainees' capacity and progress toward becoming interdisciplinary scientists commonly rely on external evaluators and their faculty colleagues who supervise IGERT trainees. PIs also noted that their projects monitor trainee publications and

presentations, post-graduation placements, and research collaborations beyond IGERT. Some PIs noted that their projects monitor progress via project-specific interdisciplinary competencies.

PIs and trainees were asked to report more specifically on the mechanisms by which projects develop the skills required for interdisciplinary research. PIs described which structured activities their projects offer, and trainees described those graduate school learning experiences in which they had already participated. Key findings are summarized below about the activities provided, at the project level, trainees' perceptions of how helpful the various activities were in developing their skills, and how confident trainees were about each of the six skill areas.

- PIs identified several concrete activities that contribute to trainees' capacity to conduct interdisciplinary research: interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects. PIs reported that outreach activities represented the avenue through which they develop trainees' capacity to communicate research to laypersons.
- Trainees' reports were remarkably consistent with PI responses: over four-fifths of trainees reported that the same set of activities was helpful in developing their interdisciplinary research capacity across competency areas: courses and seminars in multiple disciplines, interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects. A similar pattern was evident in both trainees' and PIs' responses about outreach activities as the mechanism for learning to communicate research effectively to lay audiences: 90 percent of trainees rated outreach activities as the most helpful activity for that skill area in particular, as did over half of PIs.
- The vast majority of trainees reported that they had participated in the following four IGERT activities: courses/seminars in multiple disciplines (97 percent), interdisciplinary courses (95 percent), hands-on laboratory and/or field experiences in disciplines related to the IGERT project (84 percent), and interdisciplinary team research projects (82 percent). Just over half (60 percent) indicated that their IGERT training helped them gain depth of knowledge in a single discipline.
- Examination of differences in trainees' responses by gender revealed no significant differences; given wide variation in number and types of disciplinary affiliations, the study team could not examine subgroup differences. Trainees who indicated they were closer to graduation, however, reported having more confidence in their abilities related to conducting interdisciplinary research, and not surprisingly, had participated in a larger number of IGERT activities.
- The majority of trainees reported that they were confident or very confident across the study's six skill areas essential for conducting interdisciplinary research, ranging from over 90 percent who were confident in their ability to work in interdisciplinary teams and to communicate research in one discipline to researchers trained in other disciplines, to 71 percent who were confident about applying approaches and tools from multiple disciplines to address a research problem.

Finally, the study team asked PIs to describe any successes and challenges posed by their respective IGERT projects, and trainees were invited to respond about any challenges they have experienced.

- PIs attributed a number of accomplishments to IGERT, including: fostering an intellectual community in which students collaborate to carry out meaningful research; engaging not only IGERT but other students and faculty; increasing the prominence of interdisciplinary research; using IGERT as a springboard for longer term institutional change; generating new research directions for faculty; and in one case, helping to establish an entire department within the host university.

- According to PIs, the two most common challenges trainees face are balancing the demands of IGERT with those of the home degree department/program, and the steep learning curve associated with learning new disciplines. One other challenge noted by PIs focused on trainees' need to learn new disciplines well enough to engage effectively in interdisciplinary research projects; this seemed particularly challenging for IGERT projects that incorporated engineering, advanced mathematics, or statistics, where some students simply did not have the academic background that prepared them for graduate level work in these disciplines.
- A minority of trainees reported that they had experienced substantial challenges related to their IGERT experience; the two most frequently cited challenges were an increased workload due to IGERT participation and trouble balancing IGERT and the degree program demands (28 and 17 percent, respectively).

Conclusions and Limitations

This descriptive study is intended to deepen understanding of how interdisciplinary research competencies are defined, operationalized and experienced in IGERT settings. The study findings are meant to provide useful program knowledge for NSF about how PIs conceptualize interdisciplinary training, and how trainees experience IGERT activities as vehicles for becoming interdisciplinary scientists.

As an exploratory study, the findings can offer insights and directions for future research, although they cannot tell us whether exposure to, or participation in, certain activities *causes* individuals to become strong interdisciplinary scientists. Note also that all the information collected is based on respondents' self-reported perceptions and experiences.

Given the project's scope, the study examines a limited number of IGERT projects (n=40) from only the 2007 and 2008 cohorts of IGERT projects, and is based upon information from those graduate students currently enrolled in those projects when the study collected data in spring 2012 (n=431). While this sample can help maximize the potential to answer the study's research questions, the study's results do not necessarily generalize to all IGERT projects. However, based on demographic and institutional characteristics, the study sample and the census of IGERT projects are generally quite similar.

Roadmap to the Report

Chapter 1 describes the current study in detail; it summarizes relevant research that frames the study, prior research about the IGERT Program, and the rationale for the current study. Details about study procedures follow, including the specific research questions addressed, the data collection and analytic methods used, and the study sample (Chapter 2). Chapter 3 begins by summarizing recent literature about the skills and capacities required to conduct interdisciplinary research graduate education. It then presents findings on IGERT project PIs' definitions of interdisciplinarity, their perceptions of the skills they believe are essential for conducting interdisciplinary research, and how PIs assess these skills, as well as trainees' perceptions of the skills they believe are important to develop through their graduate education. Chapter 4 presents findings on the specific activities IGERT projects use to develop trainees' interdisciplinary skills and trainees' reports about their experiences. Finally, Chapter 5 offers conclusions and suggestions based on findings from the study.

Chapter 1: Introduction

Chapter Introduction

The 21st century's greatest scientific challenges will require the next generation of researchers to work across disciplinary boundaries and advance interdisciplinary methodologies. The increased need for interdisciplinary approaches—and researchers who can productively function in interdisciplinary teams—has already contributed to important changes in how federal agencies support research and how universities prepare researchers. The National Science Foundation (2011a), National Institutes of Health (2008), American Association for the Advancement of Science (Derrick, Falk-Krzesinski & Roberts, 2011), National Academy of Sciences (COSEPUP, 1995), and other governmental and national organizations have made interdisciplinary research a strategic priority. Universities have responded by developing a variety of interdisciplinary training programs at both undergraduate and graduate levels to help students in science, technology, engineering, and mathematics (STEM) programs develop the knowledge, skills, and abilities to work across multiple disciplines and with researchers from other fields.

A widely cited 1995 report by the National Academy of Sciences' Committee on Science, Engineering, and Public Policy (COSEPUP), Reshaping the Graduate Education of Scientists and Engineers, recognized the need to increase America's advanced STEM workforce and restructure graduate education in these fields. The committee's major recommendations included the expansion of academic programs offered by U.S. universities, an increase in the avenues by which doctoral students can work across fields, and preparation of greater numbers of skilled graduates who can communicate complex ideas to laypersons and work well in team settings. The committee also recommended that federal agencies provide graduate training grants that promote educational and research versatility, faculty mentoring, and career guidance, including providing information on careers outside academe.

The National Science Foundation (NSF), through its interdisciplinary traineeships, has attempted to transform doctoral training by supporting interdisciplinary research preparation, in particular. The NSF Integrative Graduate Education and Research Traineeship (IGERT) program represents a major investment in interdisciplinary graduate education as a fundamental component of such research. Since its 1998 inception, the IGERT program has focused on three strategic goals:

1. To educate Ph.D.-level scientists with the depth and breadth of knowledge and skills to become leaders in their fields;
2. To catalyze changes in graduate education by establishing models for collaborative research across disciplinary boundaries; and
3. To promote diversity among participating students and the professional science and engineering workforce.

The current study focuses on the program's first broad goal by exploring how IGERT grantees are preparing their doctoral students to conduct interdisciplinary research. The study's research questions are as follows:

1. Whether and in what ways do IGERT participants (PIs and trainees) perceive the knowledge, skills or abilities drawn from the literature as important to conducting interdisciplinary research?
2. What activities do projects implement to develop trainees' interdisciplinary research capacity, as characterized by these knowledge, skills or abilities? How do projects assess trainees' development as interdisciplinary scientists?
3. How helpful do trainees perceive their IGERT training to be in developing their capacity to conduct interdisciplinary research as characterized by these six areas?
4. How confident are IGERT trainees of their knowledge, skills, and abilities in these six areas?
5. What challenges do trainees encounter with the IGERT traineeship?

This exploratory study investigates how interdisciplinary graduate training in the IGERT context is defined and operationalized; it offers insights into how IGERT projects develop their trainees' core interdisciplinary competencies via wide-ranging educational and research activities. This chapter sets the context for the current study; first, it describes the IGERT program's history and evolution, and outlines its scope and operation. Next, it describes the rationale for the current study, followed by a summary of findings from earlier, more evaluative, studies. The chapter concludes with a section summarizing the literature on interdisciplinary training, and presents the six interdisciplinary competencies explored by the study team.

IGERT Program History and Evolution

The IGERT program is a substantial endeavor designed, in large part, to address a national need for advancing scientific and technological innovation through research that blends more than one discipline in both approach and in the formulation of research questions. The program addresses its goals by providing grants to institutions of higher education to support—financially and through interdisciplinary research and educational enrichment activities—U.S. citizen or permanent resident STEM doctoral students interested in interdisciplinary research opportunities and careers. Most IGERT projects are led by one Principal Investigator (PI) in a single discipline, working with co-PIs from collaborating departments or institutions. Participating faculty develop and implement a series of training activities that include, among other things, interdisciplinary courses and seminars, some of which are team-taught by IGERT faculty, cross-department laboratory experiences, and off-campus internships.

Typically funded for two years, the graduate students (often referred to as "IGERT Trainees") engage in these activities while enrolled and meeting the requirements of a single-discipline Ph.D., although some IGERT projects have developed new, interdisciplinary degree programs. The collaboration of IGERT faculty across departments, institutions, and in some projects, across international boundaries, provides trainees with a cross-cutting interdisciplinary experience.

Over the program's 15-year history, NSF has fine-tuned IGERT in response to new and emerging fields as well as changes in agency priorities and recommendations.[1] Recent examples include an emphasis on providing IGERT trainees with the skills to communicate to lay audiences (National Science Foundation, 2010) and new graduate education models that promote hands-on learning in an environment that supports innovation and allows trainees to understand the societal benefit of their research (National Science Foundation, 2011b).

Program Scope and Operation

As of fall 2012, NSF's IGERT program had awarded 296 grants to 125 universities, awarding 6,700 trainee fellowships between the years 1998-2011. The financial commitment has been commensurate to the reach of the program. With increases in funding amounts in recent years, IGERT awards are approximately $3.0-3.2 million and five years in duration; the majority of funds support trainee stipends of $30,000 per year. Awards are granted to institutions that demonstrate a commitment to integrative research and education and that have the potential to institutionalize those elements of IGERT projects that prove successful in training the next generation of interdisciplinary scientists.

Managed by the Division of Graduate Education within NSF's Education and Human Resources directorate, IGERT is an NSF-wide effort involving the following directorates:

- Biological Sciences (BIO)
- Computer and Information Science and Engineering (CISE)
- Education and Human Resources (EHR)
- Engineering (ENG)
- Geosciences (GEO)
- Mathematical and Physical Sciences (MPS)
- Social, Behavioral, and Economic Sciences (SBE)
- Office of Polar Programs (OPP)
- Office of Integrative Activities (OIA)
- Office of International Science and Engineering (OISE)
- Office of Cyberinfrastructure (OCI)

Individual IGERT projects can align with multiple directorates at once,[2] based upon data collected through the program's annual performance reporting system, called the Distance Monitoring System (DMS). IGERT projects are also categorized by their respective interdisciplinary themes or focal topics (e.g., sustainability might represent one such theme, while bioinformatics, materials science and engineering might represent another project's focal topics); these serve as the foundation for trainee activities and also represent interdisciplinary topics of strategic importance to NSF, and may signal

[1] One example is a 2008 NSF workshop that focused on the importance of interdisciplinary research for "economic and societal growth and vitality" (National Science Foundation, 2009, p.1) and the role and progress of such research and related graduate training. Among the recommendations was the need to develop mechanisms to support interdisciplinary teams and thesis research, as well as financial support and formal recognition of graduate students pursuing interdisciplinary programs of study.

[2] As described in more detail in Chapter 2, the 40 IGERT projects examined in the current study align with between two and four of the seven directorates (and the managing directorate of EHR).

emerging areas of research. Themes may also be constructed by NSF in response to ideas suggested in IGERT proposals. There are 15 themes total across the IGERT projects in the current study.

IGERT projects are designed to provide doctoral trainees with a wide breadth of knowledge, skills, and abilities necessary to work in an interdisciplinary environment and conduct interdisciplinary research. Nonetheless, since the majority of students earn their degrees in a singular discipline, it is also expected that while trainees are building interdisciplinary skills, they are also firmly grounded in their "home" discipline such that they emerge with both broad interdisciplinary knowledge as well as depth of expertise in a single field.

Another area of emphasis within the IGERT portfolio is the melding of traditional scientific disciplines (e.g., physical and mathematical sciences) with social sciences (e.g., economics, sociology, anthropology). Some projects further integrate humanities disciplines. The aim is to build not only an interdisciplinary experience for trainees but also to help students explore the applicability of scientific research to policy, legal, business, and other real-world settings within which there are indeed problems that require interdisciplinary solutions. The integration of disparate disciplines often requires curricular enhancement and deep collaboration and connectivity across faculty members.

In IGERT projects, meaningful collaborations may also extend beyond a single institution; some IGERT projects partner with nearby universities, with researchers in other institutions who have complementary expertise, or with international universities—relationships that have traditionally been encouraged by NSF. One key manifestation of that emphasis is to increase cross-institutional collaborations between doctoral-granting institutions and masters-granting Minority-Serving Institutions to broaden STEM participation for American Indian/Alaska Native, Black, Hispanic, Pacific Islander, and female students, as well as persons with disabilities who might not otherwise have opportunities to engage in the types of interdisciplinary training programs supported by IGERT. Such collaborations can serve not only to strengthen connections between research-intensive and masters-granting universities, but to support efforts to attract, retain, and graduate greater numbers of underrepresented students, although projects vary in their success with respect to involving members of under-represented groups.

IGERT projects are housed within institutions with strong research infrastructures; as a result, trainees are expected to have access to cutting edge technologies, state of the art equipment, and to receive training in the latest research methods. NSF also recognizes that graduates need to be prepared for workforce entry beyond academe, thus IGERT projects are expected to offer a breadth of opportunities to trainees, including off-campus, non-academic internships as well as research exposure in international settings. Some projects also emphasize interaction with laypersons, including K-12 students and teachers, policy officials, and local (or research site-specific) community members. Activities supported by the IGERT grant, such as interdisciplinary coursework and seminars, are meant to develop trainees' skills and capacity for conducting outreach activities. (Subsequent chapters provide more detail on how IGERT projects support training of their graduate students.)

Study Rationale

Now in its second decade, IGERT has established itself as America's hallmark grant program for interdisciplinary graduate training. By supporting institutions of higher education to develop and enhance interdisciplinary research and training, NSF has contributed to establishing a broad national talent pool of interdisciplinary scientists and engineers. As IGERT's long-standing evaluator, Abt Associates (Abt) has examined key program features, including project implementation and trainees' early outcomes. The first studies of IGERT purposively examined aspects of the program critical during its beginnings, including funded project characteristics and cross-site project comparisons.

Subsequent studies (2006 and 2010) focused on the next set of evaluation priorities for NSF and the federal Office of Management and Budget, and examined initial program impact on trainees, faculty, and institutions and short-term professional outcomes of trainees, respectively.

The growing national (and international) focus on interdisciplinary research training prompted not only led to the creation of programs such as IGERT, but also strengthened the scholarly community addressing both the definition and practice of interdisciplinary science. As related fields have expanded – such as science and technology studies, integrative studies, and the science of team science – so has the literature on just how scientists conceptualize and actualize interdisciplinary research. This literature informs the current study, which seeks to explore how NSF IGERT grantees conceptualize and enact interdisciplinary education, and how IGERT trainees receive and value this training. Prior Abt studies of IGERT focused on aspects of program evaluation; the current study, by contrast, is exploratory, and attempts to expand NSF's and the field's understanding of those competencies that contribute to effective training for interdisciplinary research. This study seeks to inform IGERT program officers, PIs and STEM departments on core competencies for interdisciplinary research training while contributing to the scant body of literature on such competencies and thereby supporting NSF's strategic performance goal to "make investments that lead to emerging new fields of science and engineering and shifts in existing fields" (NSF, 2011a, p. 6).

Based on what is known about interdisciplinary training from the scholarly literature, and with guidance from NSF and external advisors, the Abt study team identified six distinct sets of knowledge, skills, and abilities (i.e., competencies) that are described in more detail later in this chapter. The study explores these competencies and uses them to understand whether IGERT participants (PIs and trainees) perceive these and other competencies as important for conducting interdisciplinary research, and further explores how IGERT projects develop trainees in these areas.

Conceptual Framework

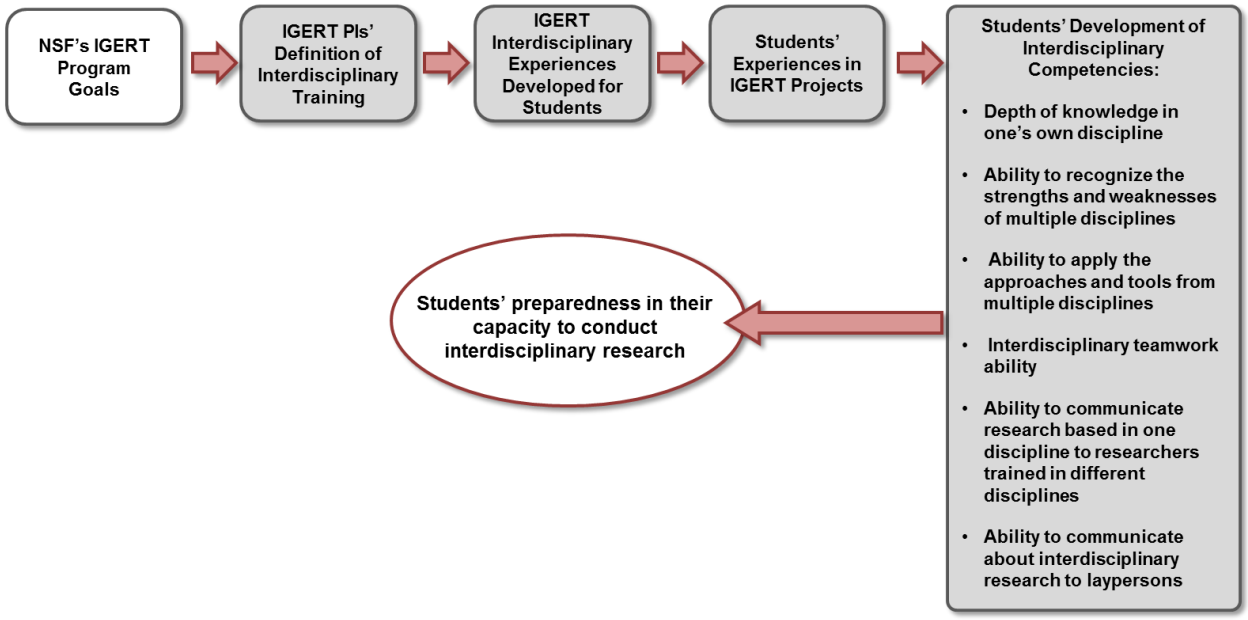
The study's conceptual approach takes the desired outcome of students' preparedness to conduct interdisciplinary research as the endpoint in outlining the IGERT program's theory of change (Exhibit 1.1). Each individual IGERT PI interprets the program goals in the context of his/her circumstances and experiences, and develops a set and sequence of activities and experiences for IGERT students accordingly. NSF provides considerable latitude to IGERT PIs and institutions in structuring, designing, and implementing project components, and in deciding whether project activities are required or optional. In general, NSF is not prescriptive in its program requirements; the expectation is that projects will offer training through exposure to research that spans multiple disciplines, development of communication and teamwork skills, and training experiences relevant to both academic and nonacademic careers. However, IGERT projects can and do differ in how each project develops and implements activities that reflect their understanding of interdisciplinary research, individual interdisciplinary research themes, institutional setting, and students' interests and backgrounds.

IGERT projects support individual doctoral students. Each trainee usually receives two years of funding while participating in IGERT activities, and many continue to participate in IGERT-sponsored activities beyond the funding period. Students' individual engagement in the IGERT activities is designed to increase their capacity along a range of competencies, which ultimately lead to students' increased confidence and preparedness to work in an interdisciplinary environment.

This study examines the components of this conceptual framework represented in shaded boxes in Exhibit 1.1: PI interpretation of interdisciplinary training; IGERT interdisciplinary experiences developed for trainees; trainees' involvement in IGERT; and trainees' development of specific interdisciplinary

competencies. Specifically, from PIs, the study asks about their definitions of interdisciplinary training; the interdisciplinary training activities developed by IGERT projects for students; and their perceptions of how IGERT activities increase trainees' preparedness for interdisciplinary work. The study asks trainees about their engagement in IGERT training, their perceptions of the extent to which their IGERT training helped develop specific interdisciplinary competencies, and the challenges they face in balancing the demands and expectations of the IGERT and their discipline-based programs. The study asked respondents (both PIs and trainees) about their perceptions, as it could not measure respondents' experiences or perceptions directly.

Exhibit 1.1. Conceptual Framework for Identifying Interdisciplinary Competencies in the Context of IGERT



The IGERT trainee experience, as described in Abt's prior evaluation reports, in concert with the literature on interdisciplinary education, contributed to the formation of the competencies presented in Exhibit 1.1; both are described below.

Findings from Earlier Evaluation Studies

NSF has commissioned several external evaluations of the IGERT program since shortly after the program began in 1998. Initially, program monitoring focused on the characteristics of funded projects at individual universities, and consisted of analyses of the Distance Monitoring System (DMS)[3] data, based on updates completed annually by respective project Principal Investigators (PIs), funded trainees, and other affiliated students. The Web-based survey database continues to provide descriptive information about each IGERT project (e.g., who participates in the project, how many trainees are funded and for how long, what are the structural elements of the program).

Beginning in 2002, NSF funded a cross-site analysis of the IGERT program, focusing on implementation in the projects' third year. The evaluation team, which included content area scientists, conducted monitoring site visits to projects in the first three cohorts (1998-2000).

[3] The DMS is operated by ICF Macro, a survey research and information technology company.

Each project was visited by a team that included both evaluation specialists and content experts who conducted in-person interviews with PIs, trainees, and key faculty, as well as relevant university administrators. The results led to a series of reports at the project-, cohort- and program-levels across all sites, such as the *NSF Integrative Graduate Education and Research Traineeships Monitoring Report: Boston University, The Bioinfomatics Project* (Chase and Carney, 2001)*;* the *IGERT Annual Cross Site Report: 1998 Cohort* (Chase et al., 2002)*;* and the *Contractor Annual Report and Summary of the Cross-Site Monitoring of the NSF Integrative Graduate and Education Research Traineeship Program* (Martinez et al., 2006).

Subsequently, NSF commissioned an *Evaluation of the IGERT Program's Initial Impacts* for participating students, faculty, and institutions, employing a comparison group of non-IGERT participants (Carney et al., 2006). The *Impact Evaluation* examined differences between groups of individuals—for example, the interdisciplinary training of IGERT students compared with non-IGERT students. Most recently, NSF commissioned a comparative study of the program, the *Follow-up Study of IGERT Graduates* (Carney et al., 2010), which examined short-term professional outcomes of IGERT graduates to understand whether and how the IGERT program prepared its graduate student participants for successful STEM-related careers and how IGERT graduates fared in their early careers relative to their counterparts trained through more traditional programs.

Although not generalizable across all IGERT projects, the earlier implementation-focused studies were instrumental in highlighting on-the-ground practices, and helped to set the stage for Abt's 2006 educational impacts study, which found that the IGERT program had a measurable effect in altering participating students' graduate educational experiences, supporting faculty engagement in interdisciplinary teaching and research, and advancing interdisciplinary graduate education within grantee institutions (Carney et al., 2006). Findings from the 2006 impact study specifically aligned with the IGERT program's three major goals:

- *Educating Ph.D. Scientists and Engineers*: Compared to their non-IGERT peers, IGERT trainees reported greater opportunities to learn about other disciplines, interact with faculty and students from other disciplines, and work on multidisciplinary projects.
- *Catalyzing a Cultural Change in Graduate Education*: IGERT faculty members reported that IGERT enabled them to establish work with colleagues in other departments and exposed them to new ideas, including new research techniques.
- *Facilitating Diversity*: IGERT PIs and faculty members reported the successful recruitment of high quality students, and in some cases, the availability of IGERT was a deciding factor in students' decision to attend graduate school.

The impact of IGERT on trainees, in particular, demonstrated programmatic success in developing students' interdisciplinary perspectives, research abilities, and teamwork and communication skills, as well as exposure to a wide range of careers. IGERT PIs expected their students to become experts in more than one field, with mastery of a single discipline and the ability to work with a diversity of scientists and utilize the techniques of multiple disciplines.

The next major evaluation of the IGERT program—the *IGERT Graduates Follow-up Study*—assessed the short-term professional outcomes of IGERT graduates and IGERT trainees' preparation in the requisite research, teaching, and leadership capacities necessary for successful STEM-related careers relative to their counterparts trained through more traditional programs (Carney et al., 2010). Based on survey responses from 261 IGERT graduates:

- Nearly all (96 percent) reported that their experience positively contributed to the completion of a Ph.D., citing the most valuable factors as financial support, the respective project's interdisciplinary theme, freedom to pursue one's research interests, and access to resources, equipment, and technology.
- Over 90 percent of IGERT graduates reported that IGERT preparation, specifically, gave them a competitive edge when applying for and obtaining positions in the workforce.
- Most IGERT graduates reported using multiple disciplines in their current work and over three-quarters (79 percent) reported using two or more disciplines, including 34 percent who reported using four or more disciplines.

Examining responses from both IGERT and non-IGERT graduates (n=436), the study concluded that:

- IGERT graduates' dissertations were more interdisciplinary than those produced by non-IGERT graduates, drawing from an average of three rather than two broad disciplines, respectively.
- IGERT graduates were more likely to report drawing upon multiple disciplines in their research than their counterparts (84 versus 73 percent).
- IGERT graduates with teaching responsibilities were more likely than their peers to be teaching courses that required them to integrate two or more disciplines (63 versus 50 percent), and both groups reported that they engaged in team-teaching with colleagues in other departments or advising students from other departments.

These findings and the work of scholars studying interdisciplinary education and training represent a foundation for the current study. After over a decade of assessing IGERT project implementation, programmatic impacts, and early outcomes, Abt researchers can now fruitfully examine *how* interdisciplinary environments are formed by PIs and faculty, where PIs and trainees place importance when it comes to constructing skills to conduct interdisciplinary research, and those educational and research activities that trainees find most useful.

Summary of Research Informing the Current Study

As noted in the 1995 COSEPUP report referenced above, innovation in the 21st century occurs beyond disciplinary borders. The pace of scientific and technological advances is so rapid that it catalyzes changes across disciplines in both research approach and execution. Awareness of the speed and nature of scientific advancement is in turn spurring our research enterprise toward embracing and building interdisciplinary research collaborations—and toward efforts to provide graduate students with essential skills and experiences to become the nation's next generation of interdisciplinary researchers.

There is increasing consensus that today's complex scientific problems are more likely to be answered through "collaborative efforts of scientists who have different backgrounds, knowledge, perspectives, and expertise" (Derrick, Falk-Krzesinski & Roberts, 2011, p. 4). This consensus is reflected in the national thrust towards an academy that embraces and builds interdisciplinary research collaborations, that trains doctoral students in interdisciplinary settings, and that develops students' essential skills to become the nation's next generation of interdisciplinary researchers. However, there is no universally accepted definition of what interdisciplinary research is (or is not), nor is there a common interdisciplinary research or training experience (Derrick et al., 2011;[4] Feller, 2006).

[4] The 2011 workshop on facilitating interdisciplinary research and education was hosted by the American Association for the Advancement of Science and the Colorado Initiative in Molecular Biology.

Not surprisingly, the literature reflects substantial variation in how interdisciplinary programs are conceptualized and implemented, reflecting differing interpretations and definitions (Jacobs & Frickel, 2009). The lines among interdisciplinary, multidisciplinary, cross-disciplinary, and transdisciplinary remain fuzzy in practice, despite attempts to draw clear distinctions among these different approaches to scientific research (Feller, 2006; Frodeman, 2011; Stock & Burton, 2011).

Yet simple awareness of the need to embrace interdisciplinary research, and prepare the next generation to function effectively in an interdisciplinary milieu, is necessary, though not sufficient, for altering the landscape to support interdisciplinary research more systematically. Universities are not necessarily hospitable to true interdisciplinary collaborations, as institutional structures, policies, reward systems, and other barriers can stifle interdisciplinary efforts. Similarly, university structures can also affect the socialization of graduate students who are pursuing interdisciplinary training (Boden, Borrego, & Newswander, 2011; Coppola, Banaszak Holl, & Karbstein, 2007; Derrick, Falk-Krzesinski & Roberts, 2011; Feller, 2006; Gardner, 2011). Nor is there systematic evidence about how universities can effectively deliver interdisciplinary training, or measure trainee learning outcomes and benchmarks, especially in science and technical fields (Aboelela et al., 2007; Boix Mansilla, 2006; Borrego & Newswander, 2010; Jacobs & Frickel, 2009; Schilling, 2001; National Science Foundation, 2009).

More recently, however, there has been increasing attention to identifying and categorizing the skills and abilities that lead to interdisciplinary competence. Some research has examined context-specific interdisciplinary research models within specific laboratory or disciplinary settings (e.g., Lattuca and Knight, 2010; Nersessian, 2009), research team dynamics and processes in interdisciplinary collaborations, (Balakrishnan, Kiesler, Cummings, & Zadeh, 2011; Falk-Krzesinski, et al., 2011; McNair, Newswander, Boden, & Borrego, 2011), and the characteristics of students entering interdisciplinary programs as well as traits that make them successful (Boden, Borrego, & Newswander, 2011; Gardner, 2011).

The current study draws most heavily on the working definition of interdisciplinary competence as developed by Lattuca and Knight (2010) and interdisciplinary learning outcomes as defined by Borrego and Newswander (2010). Through an extensive review of the engineering education and higher education literatures, Lattuca and Knight (2010) define such competence as having the ability to understand and utilize knowledge and modes of inquiry drawn from disciplines other than one's own. Such use of knowledge involves the following skills: a) an appreciation of various disciplinary perspectives; b) an ability to incorporate and evaluate multiple disciplinary approaches to problem-solving; c) an ability to recognize the strengths or weaknesses of one's own disciplinary perspective; and d) an ability to recognize the shared assumptions, skills, or knowledge among disciplines. Borrego and Newswander (2010) also conducted an analysis of peer-reviewed literature, including interdisciplinary studies in humanities and social sciences fields, and reviewed information from 129 funded IGERT proposals. The researchers then identified five similar categories of learning outcomes for interdisciplinary education, including: a) disciplinary grounding; b) integration; c) teamwork; d) communication; and e) critical awareness.

Core Interdisciplinary Competencies

Informed by Abt's previous work, the literature on interdisciplinary research and training summarized above, and guidance from NSF as well as the study's external panel of experts, the Abt study team identified six competency areas:

1. Depth of knowledge in one discipline or field of study
2. Ability to recognize the strengths and weaknesses of multiple disciplines

3. Ability to apply the approaches and tools from multiple disciplines to address a research problem
4. Ability to work in a team with individuals trained in different disciplines
5. Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines
6. Ability to communicate about interdisciplinary research to non-academic audiences (laypersons)

The study used these competency areas as the basis for collecting systematic data from PIs and trainees via interviews and surveys, respectively; the next chapter describes the study's overall approach and data collection procedures.

Chapter 2: Study Methodology

Chapter Introduction

The current study explores how IGERT institutions are preparing Ph.D. students to conduct interdisciplinary research by examining the knowledge, skills, and abilities that IGERT projects seek to develop in their doctoral students. This chapter describes the study's guiding research questions, data collection activities and analytic methods, characteristics of the study sample, and PI and trainee response rates.

Research Questions

The study seeks to answer the following research questions:

1. Whether and in what ways do IGERT participants (PIs and trainees) perceive the knowledge, skills or abilities drawn from the literature as important to conducting interdisciplinary research?
2. What activities do projects implement to develop trainees' interdisciplinary research capacity, as characterized by these knowledge, skills or abilities? How do projects assess trainees' development as interdisciplinary scientists?
3. How helpful do trainees perceive their IGERT training to be in developing their capacity to conduct interdisciplinary research as characterized by these six areas?
4. How confident are IGERT trainees of their knowledge, skills, and abilities in these six areas?
5. What challenges do trainees encounter with the IGERT traineeship?

Overall Approach

To address the above research questions, the study team used a mixed-methods research design that incorporates both qualitative and quantitative data from three major sources:

- Interviews with IGERT Principal Investigators;
- Surveys administered to current and former IGERT trainees who were still students when the study collected data; and
- Project-level information provided by the IGERT Program Distance Monitoring System (DMS), an annual Web-based survey of all IGERT Principal Investigators and trainees.

Both PI and trainee respondents were drawn from the universe of active IGERT projects that received their awards in 2007 or 2008. PI interview data provide information on the activities that IGERT PIs and faculty use to develop interdisciplinary competencies, as well as the perceived importance of these competencies in training interdisciplinary researchers. Surveys asked trainees about how important they perceive interdisciplinary competencies to be, the competencies' importance in conducting interdisciplinary research, and the individual IGERT activities that contribute to their development. The DMS data provide information on project-level characteristics and IGERT trainees' demographic characteristics.

Sample

The PIs and trainees who participated in the study (the study sample) were drawn from all projects funded in 2007 and 2008 (40 distinct IGERT projects, housed in 35 institutions). The sampling frame for projects was deliberately constructed to meet the following criteria: representation of projects funded across a range of IGERT themes; projects that were active and operational long enough to have moved beyond initial implementation; projects likely to have trainees at different points in their graduate education; and projects housed within a diverse set of higher education institutions.

Selected Project Characteristics: Study Sample and All IGERT Projects

According to the DMS, as of fall 2012, the IGERT program had supported over 6,700 trainees (1998 to 2011 cohorts) through 296 projects housed in 125 institutions. This section compares particular project-specific characteristics of the purposive sample of projects to all IGERT projects (1998 through 2011 cohorts). Findings are based on data from the 2011-2012 IGERT DMS; these data include information for all IGERT projects awarded from 1998 to 2011 (N=296), as well as data from the IGERT Resource Center (www.igert.org).

IGERT projects on the whole, and within the study sample, span a range of interdisciplinary topics and draw from multiple disciplines (and thus NSF directorates), given emerging areas of interdisciplinary research. Each IGERT project is based on an interdisciplinary research theme that draws from multiple disciplines. The IGERT themes are dynamic; they can and do change to reflect emerging areas of scientific research. Almost all IGERT projects represent more than one research theme. The most prevalent research themes across projects in both the study sample and the census of 1998-2011 IGERT cohorts include sustainability, computational science and engineering, human and social dimensions of new knowledge and technology, and materials science and engineering (Exhibit 2.1). The proportions of projects aligned with various interdisciplinary research themes are generally similar across both groups.

Exhibit 2.1. Interdisciplinary Research Themes, By Study Sample and All IGERT Projects

Research Themes	IGERT Projects in Study Sample [a]	All IGERT Projects [b]
	N (%)	N (%)
Bioinformatics	5 (13)	31 (10)
Biological evolution and development	8 (20)	36 (12)
Civil infrastructure monitoring and improvement	3 (8)	13 (4)
Climate change: impacts and factors	10 (25)	36 (12)
Computational science and engineering	16 (40)	96 (32)
Diverse device development	6 (15)	41 (14)
Energy: alternate and renewable resource and conservation	7 (18)	37 (13)
Entrepreneurialism	3 (8)	27 (9)
Human and social dimensions of new knowledge and technology	15 (38)	100 (34)
Materials science and engineering	13 (33)	70 (24)
Nanoscience: engineering and technology	6 (15)	49 (17)
Neuroscience: biology and psychology	2 (5)	19 (6)
Sensing, signals, imaging and signals processing	8 (20)	47 (16)
Sustainability: ecology and the environment	18 (45)	95 (32)
Water	1 (3)	16 (5)

Notes:

Percentages sum to more than 100 because individual projects are aligned with multiple themes.

[a] IGERT projects in study sample (n=40). Missing=0 projects

[b] All IGERT projects (1998-2011 cohorts; n=296). Missing=38 projects.

Exhibit reads: A total of 5 IGERT projects from the study sample and 31 across all projects align with the Bioinformatics research theme.

Source: http://www.igert.org/projects (accessed 10/11/12)

Selected Institutional Characteristics: Study Sample and All IGERT Grantee Institutions

As might be expected, IGERT projects are housed in doctorate-granting research universities. Exhibit 2.2 displays the Carnegie classifications of institutions in the study sample (n=36) and all IGERT grantee institutions (n=125). Over four-fifths of institutions represented in the study sample (that is, the projects in the 2007 and 2008 cohorts) are doctorate-granting research universities with very high research activity; 17 percent are doctorate-granting research universities with high research activity. The proportions for *all* IGERT grantee institutions are slightly lower (69 percent) for doctorate-granting research universities with very high research activity and slightly higher for doctorate-granting research universities with high research activity (one-quarter). These modest differences may reflect changes in NSF priorities over time, as the IGERT program was not initially limited to Ph.D.-granting institutions or to supporting only Ph.D. students.

Exhibit 2.2. Frequency of IGERTs among Institutions with Research and Doctoral Carnegie Classifications

Carnegie Classification	IGERT Grantee Institutions in Study Sample [a] N (%)	All IGERT Grantee Institutions [b] N (%)
Doctorate-granting Universities: Research Universities (very high research activity) [c]	30 (83)	87 (69)
Doctorate-granting Universities: Research Universities (high research activity) [c]	6 (17)	31 (25)
Doctoral/Research Universities [c]	0 (0)	1 (1)
Other [d]	0 (0)	6 (5)

Notes:

[a] IGERT grantee institutions in study sample (n=36). Missing=0 institutions
[b] All IGERT Grantee Institutions (n=125). Missing =0 institutions
[c] This corresponds to the definitions used in the *Carnegie Classifications*, which differentiates among institutions with very high research activity, high research activity, and all other institutions.

[d] This includes other universities/institutions that grant fewer than 20 doctoral degrees per year.

Doctorate-granting Universities: Includes institutions that awarded at least 20 research doctoral degrees (excluding doctoral-level degrees that qualify recipients for entry into professional practice, such as the JD, MD, PharmD, DPT, etc.). Excludes Special Focus Institutions and Tribal Colleges.
Level of research activity: Doctorate-granting institutions were assigned to one of three categories based on a measure of research activity, as defined by the Carnegie classifications. It is important to note that the groups differ solely with respect to level of research activity, not quality or importance.
The analysis examined the following correlates of research activity: research & development (R&D) expenditures in science and engineering; R&D expenditures in non-S&E fields; S&E research staff (postdoctoral appointees and other non-faculty research staff with doctorates); doctoral conferrals in humanities fields, in social science fields, in STEM (science, technology, engineering, and mathematics) fields, and in other fields (e.g., business, education, public policy, social work). These data were statistically combined using principal components analysis to create two indices of research activity reflecting the total variation across these measures (based on the first principal component in each analysis).
Exhibit reads: A total of 30 IGERT institutions from the study sample (83 percent) and 87 across all IGERT institutions (70 percent) are doctorate-granting research universities with very high research activity.
Source: The 2011 Carnegie Classifications (Basic Classifications). Downloaded from http://classifications.carnegiefoundation.org/descriptions/basic.php *(accessed 1/14/2013)*

The IGERT institutions in the study sample and all IGERT projects from the 1998-2011 cohorts are distributed similarly in some, though not all regions (Exhibit 2.3); nearly 30 percent of institutions from both groups are located in the northeast and one-quarter are located in the south. There are some differences: nearly two-fifths of the study sample's IGERT institutions (39 percent) and one-quarter of all IGERT institutions (23 percent) are in the western region of the country; and 11 percent of the study sample and 22 percent of all institutions are in the Midwest.

Exhibit 2.3. Region of Country, By Study Sample and All IGERT Institutions

Region	IGERT Grantee Institutions in Study Sample[a] N (%)	All IGERT Grantee Institutions[b] N (%)
Northeast	10 (28)	36 (29)
Midwest	4 (11)	28 (22)
South [c]	8 (22)	32 (26)
West	14 (39)	29 (23)

Notes:

[a] IGERT grantee institutions in study sample (n=36). Missing=0 institutions
[b] All IGERT Grantee Institutions (n=125). Missing =0 institutions
[c] Puerto Rico is included in the Southern region

Exhibit reads: A total of 10 IGERT institutions from the study sample (28 percent) and 36 across all IGERT institutions (29 percent) are located in the Northeast.

Source: http://www.igert.org/projects (accessed 10/11/12)

Response Rates and Sample Characteristics: PI and Trainee Samples

The respective PI and trainee target samples consisted of the census of PIs (n=40) and trainees (n=852) at the selected institutions. Of the 40 PIs targeted, 38 current PIs and one former PI[5] agreed to be interviewed, for a total of 39 interviews. The overwhelming majority of interview respondents (87 percent) had been serving as the PIs on their respective IGERT grants since the proposal stage, and every interviewee had been involved with the project in some way from the beginning. Within the PI sample, there are 28 men and 11 women.

Of the 852 trainees in the initial sample, 254 had already graduated/exited from their doctoral program and were thus excluded; the final trainee sample was 598. The final sample included students: (a) receiving IGERT funds; and (b) enrolled in their graduate programs but no longer receiving funding. A total of 431 (72 percent) of the trainees eligible to participate completed the survey (Exhibit 2.4).

[5] One individual had functioned as PI during the previous year, when the original PI was on sabbatical, and had been involved in the IGERT project from the beginning.

Exhibit 2.4. Trainee Sample Size and Survey Response Rates

Sample	N
A. Initial trainee sample [a]	852
B. Final survey sample [b]	598
C. Number of completed & partially responded [c] surveys	446
D. Number of completed & partially completed [d] surveys	431
Response Rates	**%**
E. Response Rate (d/b)	72.10%
F. Cooperation Rate (c/b)	74.60%

Notes:

[a] The study uses the term sample to refer to targeted students, because it is a sample of trainees, not the population, from the study's sample of IGERT projects.

[b] A total of 254 individuals were deemed ineligible for the survey because they had already graduated/exited from their doctoral program; these individuals were thus excluded.

[c] Partial responders represent two groups: (1) "partial non-responders" (n=15) who had a total response rate below 80% and *low* response rates for selected survey questions and (2) "partial complete responders" (n=2) who had a response rate below 80% and *high* response rates for selected survey questions.

[d] This number includes 429 "complete" and 2 "partially complete" surveys.

Exhibit reads: There were 852 trainees in the study's initial target sample.

Source: IGERT DMS; communications with individual PIs, project coordinators and trainees; IGERT trainee survey

While IGERT funding generally covers the first two years of graduate study, the respondents in the study sample were at different stages of graduate education. According to the 2010-2011 DMS, the majority of the trainees in the study sample (71 percent) were in their first through fourth year of graduate training, and about one-quarter of trainees (27 percent) were in their fifth to seventh year of graduate education. Additionally, the trainee survey data revealed that the respondents' degree fields span a wide range of disciplines. Two-thirds (68 percent) of study trainees reported that they expect to receive their doctoral degree in a single discipline; life sciences and engineering represent the most commonly selected broad disciplinary areas. Across all trainees, the average number of disciplines mentioned was 1.4, compared to 2.2 for trainees who expected to receive degrees in multiple disciplines. Of the nearly one-third (32 percent) of trainees who reported that they expect to receive their degrees in multiple disciplines, the disciplinary combinations were so specialized that there are few consistent patterns in the combinations reported.[6]

Demographic characteristics of the trainee sample and the population of IGERT trainees are presented in Exhibit 2.5. Trainees funded between 1998 and 2011 (N=6,798) are included when reporting data on the characteristics of all IGERT trainees. Although the trainee sample for the study represents just a small proportion of all IGERT trainees (9 percent), the gender distribution of the two groups is similar: 42 percent of the study sample and 40 percent of all IGERT trainees are female. In both groups, the majority of trainees identified their race as White (79 and 81 percent, for the study sample and all trainees, respectively). Twenty-one percent of IGERT trainees in the sample belong to racial/ethnic groups underrepresented in STEM, which is slightly higher than the 16 percent among the total IGERT trainee population.

[6] Examples of such combinations include: (1) Chemical Engineering and Bioengineering/Biomedical Engineering; (2) Plant Sciences and Pharmacology, Human/Animal; Biochemistry/Biophysics and Cell/Molecular Biology; (3) Ecology and Microbiological Sciences/Immunology; and (4) Civil Engineering and Environmental Engineering.

Exhibit 2.5. IGERT Trainees' Demographic Characteristics

Demographic Characteristics	Study Sample N (%)	All Trainees N (%)
Gender		
Female	244 (42)	2546 (40)
Male	339 (58)	3822 (60)
Race		
American Indian or Alaska Native, only	18 (3)	48 (1)
Asian, only	44 (8)	509 (9)
Black or African American, only	15 (3)	345 (6)
Native Hawaiian or other Pacific Islander, only	0 (0)	10 (0)
White, only	417 (79)	4666 (81)
Multi-racial (two or more races)	32 (6)	175 (3)
Ethnicity		
Hispanic	61 (10)	389 (6)
Non-Hispanic	472 (79)	5229 (80)
Unknown	62 (10)	879 (14)
Underrepresented Minority (URM)[c]	116 (21)	930 (16)

Notes:

[a]Trainees in study sample (n=598). Gender: Missing=15; Race: Missing=72; Ethnicity: Missing=3; Underrepresented Minority: Missing=47.
[b] All Trainees (n=6,798). Gender: Missing=430; Race: Missing=1045; Ethnicity: Missing=301; Underrepresented Minority: Missing=889.
[c] URM is composed of the following: Hispanic, American Indian, Alaskan Native, Black, Native Hawaiian, or Pacific Islander

Exhibit reads: A total of 244 IGERT trainees from the study sample (42 percent) and 2,546 of all IGERT trainees (40 percent) identified their gender as female.

Source: 2011-2012 IGERT Distance Monitoring Data

Data Collection Instruments

The Abt study team interviewed the 39 PIs between April and July, 2012. (The interview protocol is appended; see Appendix B.) The semi-structured interviews averaged about 45 minutes in length and focused primarily on how IGERT projects deliver interdisciplinary research training through questions that asked specifically about those activities that develop trainees' knowledge, skills, and abilities (i.e., competencies). PIs were also asked about their initial reasons for applying for IGERT funding, what they look for in prospective trainees, and any implementation challenges and successes associated with IGERT.

The study sent individualized e-mail invitations to IGERT trainees to complete a 20-25 minute web-based survey (see Appendix C) in April to July 2012. Trainees were asked to rate the importance of the study's six competencies for conducting single-discipline-based and interdisciplinary research; about their perceived levels of confidence in each of the six competency areas; their participation in a specific set of IGERT activities and how such participation has (or has not) contributed to developing their skills in the six competency areas; and whether they faced any challenges related to their participation in IGERT. The majority of questions used Likert-type scales, and respondents were asked to provide additional comments via a small set of open-ended questions.

Analytic Approach

The study employed two analytic approaches to answer the research questions: (1) analyses of topical themes that emerged from open-ended qualitative responses (i.e., PI interviews and open-ended survey responses), and (2) descriptive analyses of quantitative data (i.e., survey responses). Together, the analyses provide an overview of IGERT activities on the respective campuses and how these activities work to develop trainees as interdisciplinary researchers—from both the PI and trainee perspectives. Qualitative responses from interview transcripts and from open-ended survey responses were systematically analyzed using qualitative coding and analysis software. With the research questions in mind, we developed preliminary sets of codes and sub-codes as a starting point for coding. An inductive coding process was used during the preliminary analysis so that codes were refined or new codes were generated in response to emergent themes within the responses. During the coding process, the study team held regular analytic meetings to review the data, discuss emerging themes, and agree on refinements to coding and analysis strategies.

Quantitative data analysis consisted of simple descriptive statistics. For example, means or percentages and measures of dispersion were calculated to illustrate central tendencies and variation; cross-tabulations were conducted to illustrate differences in response patterns between groups or distributions across subgroups of interest.

Strengths and Limitations of the Study

This study is the first to examine, within the IGERT program, the mechanisms or features identified in the literature as salient to the development of interdisciplinary research skills. The current study provides details on how IGERT projects are conceptualized and implemented by PIs, and how respective projects are experienced by trainees, in terms of trainee development as interdisciplinary researchers. There are, however, limitations to the study design. First, the skills, abilities, and knowledge areas being examined by the study are, by necessity, exploratory. This is a reflection of the current state of the field, in which there is neither a standard definition of interdisciplinarity, nor a commonly accepted set of outcomes that one might expect from interdisciplinary training and research. A second limitation is that information on outcomes in this study is based on self-reported data by PIs and trainees; similarly, data on IGERT implementation and project performance related to competency development are self-reported by PIs. Student outcomes, including trainees' perceived confidence in their skills across the core competencies, are self-reported, and the study does not directly measure these skills.

Third, this study is based on a purposive sample of active IGERT projects. While the sample was chosen to maximize the potential to answer the study's research questions, findings are not necessarily representative of the full set of IGERT projects or grantee institutions. However, as noted earlier in this chapter, while there are some differences, trainee, project, and institution-specific characteristics were, in general, similar between the study sample and the IGERT population.

The study team began its inquiry by reviewing the core competency areas or types of knowledge needed to conduct interdisciplinary research as described in the literature. The team then identified a set of core competency areas the literature indicates would represent the essential skills or knowledge needed to succeed in interdisciplinary research. It is expected this descriptive study can contribute to an understanding of how interdisciplinary research competencies are defined, operationalized and experienced in IGERT settings, and further, contribute to useful program knowledge for NSF about how PIs conceptualize interdisciplinary training and how trainees experience IGERT activities as vehicles for becoming interdisciplinary researchers.

Chapter 3: Study Findings – Describing Interdisciplinarity

Chapter Introduction

This chapter discusses findings from the PI interviews and trainee surveys about their perceptions of the knowledge and skills required to conduct interdisciplinary research,[7] and deliberately focuses on those skills believed to be essential for conducting interdisciplinary research *in the abstract*. Key findings are presented, followed by an in depth examination of the importance and use of interdisciplinary competencies as described by PIs and trainees.

Preview of Key Findings

There is considerable overlap across the knowledge and skills both IGERT PIs and trainees believe are important in conducting interdisciplinary research based on those competencies identified in extant scholarly research:

1. Depth of knowledge in one discipline or field of study
1. Ability to recognize the strengths and weaknesses of multiple disciplines
2. Ability to apply the approaches and tools from multiple disciplines to address a research problem
3. Ability to work in a team with individuals trained in different disciplines
4. Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines
5. Ability to communicate about interdisciplinary research to non-academic audiences (laypersons)

The six knowledge or skill areas that emerged from the research were confirmed by both PIs and trainees as the primary skills they believe are important in conducting interdisciplinary research.

- Overall, the ratings provided by both PIs and trainees are remarkably consistent across the six interdisciplinary competency ratings.
- Eighty-six percent or more of PIs rated five of the six interdisciplinary competencies as important or very important to conduct interdisciplinary research. Nearly all trainees (96 percent) rated four of the six competencies as important or very important.
- Almost all PIs and trainees rated the ability to communicate research in one discipline to researchers trained in others (95 and 99 percent of PIs and trainees, respectively), and the capacity to work in a team setting with researchers from other disciplines (92 and 98 percent of PIs and trainees, respectively) as important or very important.
- An overwhelming majority of trainees (99 percent) and PIs (87 percent) indicated that the ability to understand both contributions and limitations of different disciplines, and the capacity to apply multidisciplinary approaches and tools in a research setting (86 and 96 percent, respectively, of PIs and trainees) were essential in an interdisciplinary research setting.

[7] These are the competency areas used to frame the current study, as discussed earlier in this report.

- Nearly nine of ten PIs (89 percent), and seven of ten trainees (70 percent) reported that substantial depth of knowledge in one discipline was vital for conducting interdisciplinary research.
- Fewer PIs and trainees rated the ability to communicate interdisciplinary research to non-academic audiences as important as the other competency areas (73 and 85 percent, respectively, for PIs and trainees).
- Trainees identified additional skills and abilities that they considered important for conducting interdisciplinary research, including various personality traits and transferable skills.
- PIs suggested that another important dimension of interdisciplinarity is ethical behavior, given the prevalence of extensive collaboration and co-authorship.
- PIs described a variety of qualities that they look for when selecting prospective IGERT trainees, including a strong academic background, interest and commitment to interdisciplinary research, prior research experience, and a flexible approach towards academic research.
- PIs reported that they assess trainee capacity and progress as interdisciplinary scientists in diverse ways, ranging from relying on external evaluators and their faculty colleagues who supervise IGERT trainees, to monitoring the number and quality of trainee presentations and publications, to tracking job and post-doctoral placements, to research collaborations beyond IGERT, and to assessing trainee progress by using project-specific interdisciplinary indicators.

The next sections of this chapter present detailed findings on PIs' definitions of interdisciplinarity, as well as PI and trainee perceptions of the skills they believe are essential for conducting interdisciplinary research. The chapter concludes with a discussion of how IGERT projects assess such skills across cohorts of trainees.

In this chapter, as well as in Chapter 4, we present findings from PI interviews and trainee surveys both in narrative text and in tables and charts. For ease of explanation, we generally collapse findings across categorical response options; the complete data are presented across all response categories in relevant tables in Appendix A. For example, in this chapter, we collapse PIs' responses about the relative importance of six specific interdisciplinary competencies on a four-point scale (not at all important, somewhat important, important and very important), and combine "important" and "very important" responses.

PI Perspectives: Defining Interdisciplinarity

> **"The best description I've heard is that interdisciplinarity is a soup. All the constituents blend together in a way that you don't identify the individual parts."**
>
> ***– IGERT PI***

How PIs define interdisciplinarity has clear ramifications for how they design and subsequently carry out the specific plans and activities of their IGERT awards.[8] Consistent with the breadth of definitions in the research literature, PIs' definitions of interdisciplinarity also varied; 39 interviews yielded 39 definitions. Nonetheless, there were some themes in PIs' descriptions of what embodies interdisciplinary research. The notion of melding "traditional" disciplines was often referenced as core in the definitions. According to 16 PIs, interdisciplinarity occurs when one combines or integrates traditional disciplines in ways that had not previously been explored. One PI described interdisciplinarity as *not* simply two engineering fields working together, for example, but rather fields that do not traditionally interact or overlap. Fifteen PIs described the concept in terms of methods and tools, illustrating the need for "input" or "application" from multiple disciplines when it comes to solving today's complex scientific problems. In this interdisciplinary space, solutions are new, as are the research questions; in turn prompting fresh lines of inquiry that extend the capabilities of traditional academic disciplines. One PI reflected on how his field has newer technologies and more data than ever before, making it impossible to accomplish research goals without drawing on other disciplines. Another noted that it is not so much the problem that defines interdisciplinarity, but the perspectives and tools utilized in solving that problem.

A smaller set of PIs (n=8), described interdisciplinarity as a worldview, as an overarching philosophy, or as a mindset for inquiry. One PI hopes that his trainees will "… not only be conversant in other disciplines, but will incorporate fields beyond their core area of expertise and into their "entire research world view." Reflecting on the use of various definitions to describe their work, six PIs remarked on the blending and at times lack of clarity among inter-, trans-, and multi-disciplinary research. One PI said his project deliberately tries *not* to define interdisciplinarity, while others (n=5) had a working definition about where these various terms break from one another. One PI further noted that what is interdisciplinary today may be its own discipline 20 years from now, as science itself becomes more inherently reliant on multiple and integrated disciplines to address 21st century research problems.

PI Perspectives: The Importance and Use of Interdisciplinary Competencies

Interdisciplinary Competencies in Theory

The interviews with PIs began with questions about the theoretical importance of the six aforementioned competencies in conducting interdisciplinary research on a four-point scale (i.e., not at all important, somewhat important, important, and very important). Exhibit 3.1 summarizes PIs' responses about the relative importance of each competency area.[9]

[8] The interviews with IGERT PIs included a question about the definition of interdisciplinarity; trainee surveys did not include the same question.

[9] Note that throughout this report, when exhibits present findings on importance ratings, "important" and "very important" are combined into one category; tables in the appendices present the actual numbers and/or percentages of responses in each category separately.

Exhibit 3.1. Importance of Specific Competencies in Conducting Interdisciplinary Research: PI Ratings

Interdisciplinary Competency	Very Important/ Important[a] N (%)
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	37 (95)
Ability to work in a team with individuals trained in different disciplines	34 (92)
Depth of knowledge in one discipline or field of study	34 (89)
Ability to recognize the strengths and weaknesses of multiple disciplines	33 (87)
Ability to apply the approaches and tools from multiple disciplines to address a research question	32 (86)
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	27 (73)

Notes:
Number of PIs who were asked these questions=39. Number of responses to individual questions ranged from 37 to 39.
[a] This column combines two response categories (very important" and "important") into one category. Appendix tables provide breakdowns for each category separately.
Exhibit reads: Thirty-seven PIs described "the ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines" as important or very important.

Source: PI Interview, Items 4A, 5A, 6A, 7A, 8A and 9A

Interdisciplinary Competencies in Practice

In addition to rating each of the six competencies, PIs elaborated on what makes them important or very important, how they are broadly addressed, and how the competencies are reflected in their respective training environments:

Ability to Communicate Research Based in One Discipline to Researchers Trained in Different Disciplines

Thirty-seven PIs (of 39) rated this ability as important or very important for conducting interdisciplinary research. Interview responses indicate that IGERT PIs pay particular attention to ensuring that their students learn the scientific language used in other disciplines, and further, ensuring that students can access and help construct a common language that can be used across disciplinary boundaries. PIs explained that this includes eliminating scientific and research jargon from communications with fellow trainees, faculty, and other stakeholders. It also means being able to communicate with a diverse array of researchers from different backgrounds, including in international and other cross-cultural settings. Several IGERT PIs further noted that this focus on facilitating cross-disciplinary communication for trainees in turn benefits faculty involved in the project. That is, when trainees work across disciplines, so do their faculty advisors and mentors.

Depth of Knowledge in One Discipline or Field of Study

Thirty-four PIs (of 39) rated this competency as important or very important. Most PIs commented that interdisciplinary research requires researchers to be grounded in one discipline, and further, that interdisciplinary knowledge is not meant to replace singular disciplinary expertise. Since the majority of interdisciplinary research occurs in team settings where team members each have substantial depth in a given discipline, PIs emphasized that successful teams capitalize on team members' individual areas of expertise for a given project.

While depth in one field was overwhelmingly characterized by PIs as important or very important, providing training to develop such depth is not a goal of IGERT, and consequently is not emphasized by IGERT projects. Thirty-eight PIs noted that disciplinary depth instead occurs via coursework in trainees' home disciplines and/or departments. IGERT PIs further acknowledged that without depth of knowledge in one discipline, trainees would likely face disadvantages in the job market, since universities typically hire research faculty with expertise in a specific field or discipline. Even in inherently interdisciplinary fields, one PI noted that to be successful, one must still demonstrate intellectual ownership of a key focal area.

Ability to Work in a Team with Individuals Trained in Different Disciplines

Working in a team setting, particularly with researchers from other disciplines, was rated by 34 PIs as important or very important for interdisciplinary research training. Even when PIs discussed other competency areas, they reflected on team building activities as central to the IGERT experience. Despite academe's focus on personal productivity and the independent nature of dissertation research, PIs consistently referenced team skills as important/very important. PIs noted that participation in teamwork serves to deepen trainees' understanding of the attributes, challenges, and overall applicability of using different disciplines to address a research problem. The capacity to function effectively in teams was described as an intrinsically important one, as it connects to the other competencies explored in this study. Several PIs noted, however, that one does not necessarily need to work in teams on a day-to-day basis to conduct interdisciplinary research.

> **"We tell them, you can have the most effective gizmo and if you can't communicate why it's important, it's not going to be used."**
>
> ***– IGERT PI***

Ability to Recognize the Strengths and Weaknesses of Multiple Disciplines

The ability to understand both contributions and limitations of different disciplines was rated as important or very important by 33 PIs. Approximately one-quarter of PIs (10 of 39) elaborated on this particular competency, and provided varied explanations of what it looks like in practice. Examples included: having respect for other disciplines and what disciplines can bring to a research problem; maintaining an open mind and recognition of the different attributes of other disciplines; and familiarity with how researchers in different disciplines talk about different areas of their work. One PI stressed the value of identifying the strengths [of different disciplines] alone; another described an approach designed to ensure trainees have both significant depth in their home discipline and significant knowledge in a second one. Another PI noted that some problems may simply not be well addressed by certain disciplines, but he would not characterize that as a weakness per se. Generally, PIs focused on developing trainees' capacity to understand the scientific language spoken in other disciplines—a concept that comes up across competency areas.

Ability to Apply the Approaches and Tools from Multiple Disciplines to Address a Research Problem

The capacity to apply multidisciplinary approaches and tools in a research setting was deemed important or very important by 32 (of 39) PIs. Nearly all PIs indicated that broad understanding of how diverse disciplinary approaches apply to different research problems is critical. In addition to providing exposure to application principles, PIs also emphasized the importance of building teamwork skills and helping trainees develop a common language to work across disciplinary boundaries. PIs emphasized the importance of applying tools from multiple disciplines, yet they did not necessarily expect their trainees to have mastered such application during their graduate educational experiences. Rather, PIs reported that their IGERT projects do more to expose students to potential interdisciplinary applications than ask students to apply multiple disciplines in a lab or in the field.

Ability to Communicate Interdisciplinary Research to Non-academic Audiences

Over two-thirds of PIs (27) characterized this competency as important or very important; interestingly, not all of the PIs we interviewed indicated that their respective IGERT projects have incorporated such communication activities (e.g., outreach). Seventeen (of 27) PIs described project activities that include consistent, formal outreach efforts provided to trainees; trainings or presentations with local (to the campus) K-12 teachers and students were among the most common forms of outreach. Some of the IGERT projects have a formal policy component, including trips to Washington, D.C., while others work with local community members, NGOs, and in one case, local indigenous communities.

"Other" Skills Characterized as Important

PIs described other skills or abilities they believe are essential for conducting interdisciplinary research (beyond the six described above) and also reemphasized or elaborated further upon their responses to the six aforementioned competency areas. For example, about one-third discussed skills related to communicating across disciplines and to wider audiences. About one-quarter of PIs emphasized the need for trainees to engage in ethical and responsible behavior when conducting research. A few specifically noted the value of establishing clear boundaries when engaging in collaborative work, including expectations setting around shared publications.

PI and Trainee Perspectives: The Importance and Use of Interdisciplinary Competencies

Trainees rated the importance of the study's six interdisciplinary competencies on a four-point scale (not at all important, somewhat important, important, and very important). Four of the six competencies were rated as important or very important by 96 percent or more of the trainees. Most (85 percent) considered the ability to communicate research to laypersons as important/very important. Depth of knowledge in one discipline was rated important/very important by relatively fewer trainees (70 percent). Exhibit 3.2 summarizes trainees' ratings for each competency, alongside the PI ratings discussed immediately above, for each area.

Exhibit 3.2. Importance of Specific Competencies in Conducting Interdisciplinary Research: PI vs. Trainee Ratings

Interdisciplinary Competency	Very Important/Important	
	PI Ratings N (%)	Trainee Ratings N (%)
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	37 (95)	427 (99)
Ability to work in a team with individuals trained in different disciplines	34 (92)	423 (98)
Depth of knowledge in one discipline or field of study	34 (89)	302 (70)
Ability to recognize the strengths and weaknesses of multiple disciplines	33 (87)	426 (99)
Ability to apply the approaches and tools from multiple disciplines to address a research question	32 (86)	412 (96)
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	27 (73)	367 (85)

Notes:

39 PIs were asked these questions. Number of PI responses to individual questions ranged from 37 to 39.

431 trainees were asked these questions. No (0) trainees did not answer these questions.

Exhibit reads: Thirty-seven of PIs (95 percent) described "the ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines" as important or very important. A total of 427 trainees (99 percent) described this competency as important or very important.

Source: PI Interview, Items 4A, 5A, 6A, 7A, 8A and 9A. IGERT Trainee Survey, Items B1,B2b, B3b, B4b, B5b and B6b

There were minor differences in how PIs and trainees rated the competencies. While nearly 90 percent of PIs mentioned depth of knowledge in one discipline as important or very important, 70 percent of trainees rated this knowledge area similarly (Exhibit 3.2). Perhaps this reflects the fact that trainees were selected to complete the survey precisely because their interdisciplinary graduate education had been supported by IGERT, and therefore they may have been less likely to perceive this competency area as equally important to other competencies that explicitly reference interdisciplinary research. As had PIs, trainees rated the ability to communicate single discipline-based research to researchers trained in different disciplines as one of the most important skills for conducting interdisciplinary research. Slightly fewer PIs than trainees rated communication to lay audiences as important/very important, and this was one of the lowest-rated competency areas for both trainees and PIs.

Trainees were asked to elaborate in open-ended comments about any *other* skills and abilities that they consider important in interdisciplinary research settings, and about half of the survey respondents offered comments. The skills and abilities most commonly mentioned, in about half of the responses, referenced various personality traits (e.g., interpersonal skills, flexibility, intellectual curiosity, an open mind to others' point of view, respect for others, patience) and transferable skills (e.g., interpersonal communication skills, leadership skills, and technical and organization skills), as illustrated in Exhibit 3.3 below. These and other open-ended responses provide rich context for the close-ended survey responses and often reinforce some PI comments. The emphasis on intellectual curiosity, in particular, resonates with PIs' comments about what they look for in students (discussed below).

Exhibit 3.3 Other Skills and Abilities Considered by Trainees as Important for Conducting Interdisciplinary Research

Examples of Personality Traits Trainees Described as Important

Intellectual curiosity:

"I believe the most important attribute necessary for conducting interdisciplinary research is a strong interest in the research question. This can fuel one's willingness to take the time to learn jargon, techniques, and literature from different fields, even when doing so is taking time away from within-discipline research."

– IGERT Trainee

Open-mindedness to others' points of view:

"The ability to collaborate and accept other disciplines as equally important as the discipline you are well versed in. Acceptance and non-judgment are very important in interdisciplinary research."

– IGERT Trainee

Respect:

"Half of the success of interdisciplinary research lies in finding the right open minded people to work with and showing them that you respect what they bring to the table."

– IGERT Trainee

Communication:

"Effectively communicating cross [sic.] disciplines is an important aspect of a successful project. It very easy to communicate within discipline, however between disciplines is difficult. Overcoming this obstacle is the key to success in developing a successful interdisciplinary project."

– IGERT Trainee

Leadership skills:

"Management of complex interdisciplinary teams so that workflow progresses smoothly."

– IGERT Trainee

Technical skills:

"…. students must also be able to bring a skill to the table, like knowing how to use a particular piece of equipment, have access to a special database or research site, or be able to use a certain statistics program. Researchers are often looking for help with projects in their field; being able to provide a skill they need opens the door to incorporating perspectives from your field."

– IGERT Trainee

Reaffirming the importance of recognizing strengths and weaknesses of other disciplines:

"It is important to understand how disciplines complement one another, which is somewhat similar to knowing their strengths and weaknesses, but also helps one understand when the sum of two approaches together would yield greater results than the sum of the two approaches in isolation (synergistic effects)."

– IGERT Trainee

PI Perspectives: Selection of Prospective IGERT Trainees

The selection of graduate students for participation in the IGERT program is one of PIs' greatest responsibilities. We asked PIs to describe the qualities they seek when selecting prospective IGERT trainees. First and foremost, PIs emphasized identifying high quality students with a strong academic background (e.g., GPA, standardized test scores) or similar qualifications for successful performance as graduate students. PIs noted that the selection process of trainees is considerably streamlined by virtue of having a pool of eligible students already admitted into selective graduate programs, and who consequently are of high caliber. About half of the PIs reported that they look for additional qualities, including interest and commitment to interdisciplinary work as well as the specific mission of individual IGERT projects, open-mindedness, and prior research experience. Three PIs noted that they specifically look for evidence that students are excited about interdisciplinary work.

Another factor considered in the selection process is a prospective trainee's ability to commit the time required for participation in IGERT. The majority of PIs remarked that students must be both committed to interdisciplinary work and to the project itself such that trainees can sustain the required workload. One PI commented that prospective IGERT students usually have a number of funding options available to them, some with greater stipend amounts, and therefore the potential to train specifically as an interdisciplinary researcher is what makes the IGERT traineeship appealing for students.

About one-third of PIs commented that successful students have an open mind or flexible academic research outlook. PIs described this flexibility in terms of students' relative comfort in taking risks, having an adventurous outlook, or being willing to take on intellectual challenges. Finally, roughly a quarter of PIs look for prior research experience, particularly at the undergraduate level. One project specifically taps into students who have participated in NSF's Research Experiences for Undergraduates program. Another project looks for students who have a substantial amount of related professional experience such that trainees can appreciate the integrative elements of IGERT. The PI of this project acknowledged that this approach is not typical for departments like his; however, the strategy allows him to attract students who otherwise may not have attended this particular research university. For this specific project, therefore, IGERT is attracting a somewhat different profile of doctoral students, and is thus widening the pool of interdisciplinary researchers.

PI Perspectives: Assessment of Interdisciplinary Research Progress

We asked PIs to describe how they assess and/or monitor students' development as interdisciplinary researchers, to learn about any specific measures, indicators, or strategies used by IGERT projects related to interdisciplinary assessment. Assessment of trainees' progress in developing interdisciplinary skills is not a requirement of IGERT projects, and therefore we did not expect all PIs to reference any such assessments; however, given the study's emphasis on how PIs conceptualize and execute training to develop students' interdisciplinary competencies, we included a question on this topic. Indeed, not all PIs reported that they assess interdisciplinarity; of those who did, assessment was carried out by external evaluators and supervising faculty (referenced by 14 and12 PIs, respectively). A smaller number of PIs (4) reported that trainees' progress is monitored relative to project-specific interdisciplinary competencies or content knowledge. Below, we summarize how interdisciplinary capacity was assessed.

Approaches Used to Assess Interdisciplinary Progress

External Evaluators

According to PIs, external evaluators typically do not assess students' growth as interdisciplinary researchers directly; instead, they often chronicle students' attitudes and perceptions.

For example, they monitor students' views of themselves as interdisciplinary researchers and their progress over time, or faculty perceptions of trainee progress vis-à-vis academic performance as well as research skills. PIs indicated that their external evaluators use a range of data collection strategies from which to draw and analyze qualitative or quantitative descriptive data, including trainee surveys, interviews and focus groups with trainees, interviews with IGERT faculty, attendance at IGERT events, and course evaluations.

One project's external evaluator is tracking the professional connections of IGERT trainees and a comparison group of non-IGERT students. The evaluator is utilizing a professional networking software package and is ultimately interested in whether analyses of professional networks and networking activities can inform an understanding of interdisciplinary practice and the value-added contributions of programs like IGERT in establishing interdisciplinary networks. The PI from this project planned to prepare a manuscript with the evaluator for circulation in late 2012. A different project reported is using an external advisory committee to assess progress. This group recently visited the project and spent two days reviewing project data and speaking with IGERT community members. The PI is hopeful that the committee will help ascertain how students have developed over time or if the project can, according to the PI, "even assess this at this point."

While PIs reported that they generally find the feedback from their external evaluators informative, nearly half acknowledged that the external evaluation activities were limited in scope. One PI, for example, observed that advanced quantitative analyses were not appropriate for such a small number of trainees in a cohort (generally five students). Another PI noted that measuring how students' interdisciplinary perspectives have changed since joining IGERT is not possible, since the project only collects information *after* the students have already become IGERT trainees.

Monitoring and Tracking Trainee Outputs

About one-third of PIs (12) reported that they assess trainee progress via IGERT faculty (including those teaching IGERT courses), advisors, and dissertation and other committee members who monitor trainee work and progress, especially research progress. One project created a "professional development portfolio" for each trainee at the start of the program to track trainees' involvement in all IGERT activities (e.g. coursework, seminars, and research assignments). Another uses a faculty committee that monitors trainees' progress, which is reported annually to project leadership. In yet another project, once each semester, trainees submit a "progress chart" for faculty to review and then discuss with the students in a face-to-face meeting. Trainees update their charts after each meeting and use it as the basis for the next semester's review conversation.

PIs also report tracking particular student outputs, including the numbers of papers published (7 projects), presentations (3 projects), job and post-doctoral placements, and collaborations beyond IGERT (2 projects each). PIs described these types of feedback as providing the right information at the right time, although they also acknowledged that tracking outputs alone does not necessarily constitute assessment of trainees' development as interdisciplinary researchers.

Competency/Content Knowledge Assessment

Four projects measure interdisciplinary content knowledge or competencies in the evaluation process. One of these projects has identified 10 competencies for which students develop individual learning plans that are approved and monitored by a faculty committee. Each student is assigned a faculty "advocate" to discuss that student's progress and skill development in the 10 areas listed in the student's plan. Some of the competencies developed by this IGERT project are similar to the competencies that are the focus of this study, including: interdisciplinary breadth; multidisciplinary collaboration; research design;

disciplinary depth; cross-cultural skills; language skills; communication skills; and applied research. Another project uses an end-of-year oral exam to assess students' development on five competencies; trainees are presented with questions distributed across competencies related to their respective IGERT concentrations. Two other projects test students' content knowledge at predetermined junctures. One implements a "before and after" assessment (in each IGERT course) based on course content that includes open-ended questions to capture application knowledge. The other has included research content as a construct measured by the project's external evaluator, via a written test, for example, that asks students to explain or compare and contrast an interdisciplinary concept.

Challenges of Assessment

About one-third of PIs reported uncertainty about how best to assess their trainees, or about how best to measure the right things. Several PIs noted the inherent challenge of assessing interdisciplinary skills and the development of these skills. One PI noted information to assess students' level of interdisciplinary skill or knowledge is not available until after students have entered the IGERT program, thus no benchmark is available to evaluate how much progress trainees make over time. Others report being challenged by identifying the appropriate metrics to assess discrete skills such as leadership and teamwork. Another challenge is fitting in project evaluation alongside the many other administrative demands of an IGERT project. For example, one PI noted that the everyday rapid pace required to keep the project going makes fitting in a thorough assessment process very difficult.

Chapter 4: Study Findings – Interdisciplinarity in Practice

Chapter Introduction

This chapter describes the contexts within which the study sample of IGERT projects operates. It summarizes how PIs operationalized their respective IGERT projects, sought IGERT funding and built support for their projects amongst faculty colleagues. It describes the trainees' experiences in detail, focusing on the specific activities in which they have engaged, and whether and how trainees perceive those activities as helpful in the development of interdisciplinary skills.

Preview of Findings

Key findings include:

- The activities PIs most frequently cited as vehicles for developing trainees' capacity to conduct interdisciplinary research included interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects.
- PIs reported that outreach activities were most frequently used to develop trainees' capacity to communicate research to laypersons. The large majority of trainees (90 percent) rated outreach activities as the most helpful activity for developing this specific competency area.
- The large majority of the trainees (from 86 to 88 percent) reported that their overall IGERT training was helpful or very helpful in enhancing four of the six identified competency areas.
- The vast majority of trainees reported that they had participated in the following four IGERT activities: courses/seminars in multiple disciplines (97 percent), interdisciplinary courses/seminars (95 percent), hands-on laboratory and/or field experiences in disciplines related to the IGERT project (84 percent), and interdisciplinary team research projects (82 percent).
- Trainees consistently reported courses and seminars in multiple disciplines, interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects as the most helpful activities for developing their interdisciplinary research capacity across competency areas.
- Trainees also suggested that other skills or abilities were essential for conducting interdisciplinary research, including personality traits and transferable skills.
- The majority of trainees (from 71 to 94 percent) reported that they were confident or very confident across all six identified competencies; in particular, almost all trainees were confident or very confident in their ability to work in interdisciplinary teams (94 percent), and to communicate research in one discipline to researchers trained in other disciplines (90 percent).
- The most common successes of IGERT projects reported by PIs were increased visibility of interdisciplinary research among non-IGERT faculty and graduate students, and creation of a sense of community among IGERT faculty and trainees.
- PIs attributed a number of accomplishments to IGERT, including establishing a sense of community in which students come together and do meaningful work; engaging not only IGERT but other students and faculty, and thereby increasing the visibility of interdisciplinary research;

using IGERT as a springboard for longer term institutional change; generating new research directions for faculty, and in one case, helping to establish an entire department within the host university.

- PIs observed that trainees faced two common challenges: balancing the demands of IGERT with those of the home degree department, and the steep learning curve associated with learning new disciplines.
- Less than one-third of trainees reported that they had faced substantial challenges related to their IGERT experience; the two most frequently cited challenges were an increased workload due to IGERT participation (28 percent) and trouble balancing IGERT tasks with those of trainees' degree program (17 percent).

As in Chapter 3, for ease of presentation, categorical response options are collapsed in exhibits and accompanying text discussion. (Appendix A presents tables with data across all response categories.)

PI Perspectives: Obtaining Support for Interdisciplinary Research

PIs offered varied explanations about why they had sought support for interdisciplinary training specifically. The most common reasons included a history of conducting interdisciplinary research, with faculty across departments (or across institutions), whether formally or informally. The majority of PIs described working in an environment with existing interdisciplinary collaborations and/or an institutional culture that promotes research across departmental lines. Two PIs called this "a perfect fit." Half of the PIs described their respective IGERT projects as an outgrowth or continuation of a prior, formal grant-funded interdisciplinary project. Ten PIs specifically referenced a prior IGERT grant at their home institution as either directly feeding into their current grant or serving as a model for their proposal. Several other NSF grant programs were also described as having influenced current IGERT projects, through providing examples of other interdisciplinary research enterprises, including: Science and Technology Centers, Engineering Research Centers, Large Scale Multidisciplinary Projects, Materials Research Science and Engineering Centers, and Research Training Groups, as well as the U.S. Department of Education's Graduate Assistance in Areas of National Need grant.

About one-third of the PI respondents described how they secured faculty buy-in. Each described the process as relatively seamless, reflecting an already established interest in interdisciplinary research and training; a few also noted the appeal of an IGERT due to the prestige and financial support provided via NSF funding. PIs described their colleagues as open, interested, helpful, and/or enthusiastic about the prospect of securing IGERT funds. Other common reasons PIs offered for why they sought IGERT funding was the increasingly interdisciplinary nature of their respective fields, and/or the topics they were most interested in pursuing. More than a quarter of the PIs pointed to new, real-world applications of such interdisciplinary work; some noted the increasingly important role of science policy. Several PIs also commented on the needs of their state, local community, or industry partners (e.g., research on environmental sustainability for local communities or industry clients).

Another theme, addressed by about one-fifth of PIs, was the importance attached to training a future generation of scientists who will be able to respond to increasingly interdisciplinary scientific community research needs. Some PIs acknowledged that they sought funding because IGERT provides formal and structural support to help both students and faculty learn to work across disciplines. Finally, two PIs noted that securing IGERT funding would mean their projects could attract high quality interdisciplinary trainees.

PI Perspectives: IGERT Activities Help to Develop Interdisciplinary Skills

Prior to receipt of IGERT awards, PIs typically define (and sometimes establish) a set of learning activities they believe represent effective vehicles for delivering interdisciplinary research training. Based on a review of IGERT program components from project websites, program monitoring data, and prior evaluation studies of the IGERT program, the study team identified the following nine categories of activities across the projects:

- Interdisciplinary Courses and Seminars
- Journal Clubs and Research Brown Bags
- Courses in Multiple Disciplines and Departments
- Laboratory and Field Experiences
- Internships in a Non-Academic Setting
- Interdisciplinary Team Research
- International Research Experiences
- Mentorship from Faculty
- Outreach Activities

PIs indicated which of the above activities are used by their respective IGERT projects to develop trainees' interdisciplinary competencies (see Exhibit 4.1).[10] [A description of trainees' participation in these activities is summarized later in this chapter.] Across the study sample, examples of each of these categories of activities were reported, although individual projects varied considerably in the activities used to develop specific competencies.

[10] This set of activities reflects PIs' responses to semi-structured interview questions about the activities they use in their respective projects to enhance interdisciplinary skill development; based on PIs' responses, the activities were classified into the nine categories listed above. Note that trainees responded to a set of questions about participation in nine categories of activities.

Exhibit 4.1. Types of Activities Used to Develop Interdisciplinary Competencies: PI Reports

Specific Activity Type	Competency Area Addressed (Number of PIs)				
	Strengths and Weaknesses	Application of Tools	Team Work	Communicate to Researchers	Communicate to Laypersons
Courses in multiple disciplines	9	4	0	4	0
Interdisciplinary courses	25	24	13	26	8
International research	3	3	0	0	1
Journal club/brown bag	6	3	1	9	0
Laboratory/field experiences	14	17	7	4	3
Mentorship from Faculty	6	10	3	2	0
Nonacademic internships	7	4	3	1	3
Outreach activities	3	0	4	1	22
Team research	9	10	15	3	0
Other activities (e.g., retreats)	5	5	5	8	6

Notes:

39 PIs responded to questions about the activities used.

Exhibit reads: Of the 39 PIs who were interviewed, nine reported that their projects use courses in multiple disciplines to develop trainees' abilities to recognize the strength and weaknesses of multiple disciplines.

Source: PI Interview, Items 4B, 5B, 6B, 7B, 8B and 9B.

The format, structure, and perceived usefulness of the activities described by PIs are discussed below. The descriptions vary in length and detail, corresponding to the relative depth of PIs' comments about how their projects use these activities. The most frequently cited activities included interdisciplinary courses and seminars, laboratory and field experiences, interdisciplinary team research, and outreach activities. There were also a host of "other" (non-categorized) activities utilized across projects ranging from annual retreats to short-term or one-time trainings and events. These later activities are described later in this chapter.

Courses and Seminars in Multiple Disciplines

Courses and seminars in multiple disciplines were reported by about two-fifths of PIs; in most cases, these courses are offered in multiple departments across the institution(s) that tie into the respective IGERT theme. Generally, when PIs referenced trainee course-taking in disciplines associated with IGERT, they described specific course requirements within a given topic or substantive area; two PIs referenced the public policy sequence, for example, that trainees are expected to take.

Interdisciplinary Courses and Seminars

Interdisciplinary courses and seminars that involve trainees and IGERT faculty are fundamental to the IGERT experience.[11] Seminars, some of which are open to non-IGERT students as well, take place weekly or bi-weekly. Some such seminars are sequential in nature, while others are structured into individual sections or "modules" that address different topical areas.

[11] Other terms included "class," "workshop," "roundtable," and "colloquia."

The topics reported by PIs typically focused on providing background, theory, and overall exposure to disciplinary areas associated with a given campus' IGERT theme (e.g., "The Science and Engineering of Energy"). The module structure serves to deliver techniques and approaches aligned with the competency areas described above (see Chapter 3) as well as skill-building activities in research methods, experimental techniques, and research ethics. PIs described other professional development topics incorporated into the seminars, including career exploration, grant-writing techniques, and presentation and writing skill-building exercises. IGERT courses typically rely on multiple formats, including lectures, readings, discussions, team projects–including team research projects and other hands on-activities–and case study and writing assignments. The interdisciplinary courses and seminars enroll anywhere from a handful of trainees to as many as 80 campus-wide attendees.

Journal Club and Research Brown Bags

Thirteen PIs described using "journal clubs" designed to develop trainees' appreciation and understanding of different disciplines' approaches to research problems. The journal clubs operate via regularly scheduled discussions based on review of journal articles amongst students and faculty. One IGERT project opened the journal club to the larger STEM community; it proved so popular that the PI had to add additional sections. Three PIs noted that their respective journal club meetings provide students with an opportunity to talk to one another, interact, and network. Less formal discussions and presentations, some of which were termed by PIs as "brown bags," mainly consist of invited speakers as well as research presentations by trainees.

Laboratory and Field Experiences

Interdisciplinary laboratory and field experiences, another hallmark of the IGERT experience, can take a variety of shapes across institutions. A lab rotation model was among the approaches some PIs noted; in six projects, trainees work in different disciplinary settings over a designated time period (e.g., summer, academic year). Five projects have separate interdisciplinary laboratory courses, and several PIs explicitly referenced the connections between lab or field experiences and interdisciplinary course requirements. Regardless of their format, the learning-by-doing component was perceived by PIs as critical for providing exposure, experience, and practice in linking conceptual understanding of interdisciplinary science with practical, hands-on knowledge of related research. PIs reported paying deliberate attention to constructing interdisciplinary teams—whether in an on-campus lab or in the field—because they and their faculty colleagues recognize the benefits of not only providing hands-on experiences but also allowing students to learn from one another in these settings. The varied theoretical perspectives and prior research experiences of individual trainees, and the sharing that naturally occurs in a research team setting, all contribute to an active learning environment.

Nonacademic Internships

Just under half of the study PIs referred to nonacademic internships as a way to provide trainees with exposure to other areas of the scientific enterprise. Internship environments have an interdisciplinary component in that trainees are sharing, collaborating, and/or gaining exposure to interdisciplinary work in non-academic or real-world settings. Examples include K-12 schools, government and non-government organizations, and both large and small companies. One PI said that the experience gets students "outside their comfort zone" and into another type of problem-solving environment with colleagues from different backgrounds and areas of expertise.

Interdisciplinary Team Research

Team-based research projects are folded into several IGERT activities; most commonly, they are linked to interdisciplinary seminars and courses as well as laboratory and field research experiences. Teams in seminars and courses are generally comprised of trainees, while teams in the laboratory or in the field are typically constructed of both IGERT trainees and faculty. Across most projects, IGERT-specific team research occurs prior to students' dissertation research (and may contribute to the conceptualization of dissertation-related work) and is introduced early on in the IGERT experience, so students learn from the start what it means to work in a team setting. A handful of PIs noted, however, that team research is not always necessary and can become less relevant as students advance to candidacy. PIs also acknowledged the importance of maintaining one's individual research identity, especially when it comes to training graduate students likely to seek tenure-track faculty positions. Given the nature of academic research and the tenure process, in which rewards often reflect individual accomplishments (such as single-author peer reviewed journal articles), some PIs feel that team research should not be overemphasized. Yet PIs were nonetheless proud of the fact that trainees are able to jointly author and present alongside IGERT faculty, and seem to do so in large numbers.

International Research Experiences

Nine PIs discussed their respective projects' international research offerings. Seven referenced them in association with three interdisciplinary competencies: the ability to recognize the strengths and weaknesses of multiple disciplines; apply the approaches and tools from multiple disciplines; and communicate interdisciplinary research to non-academic audiences. Two projects structure international experiences through joint IGERT trainee and faculty travel to a specified field location where they conduct research and outreach to local communities. Other international opportunities involve individual travel to partner universities or laboratories abroad. One IGERT PI noted that the technology associated with his project is much more advanced in the country within which his partner institution is located, which provides students with exposure and training not available in the U.S.

Mentorship from Faculty

While not a formal activity, per se, 21 PIs highlighted the role of faculty advising and mentoring, chiefly through faculty involvement from disciplines outside trainees' home departments. Two PIs noted that "mentor" relationships serve that function, while others described varied types of structured interactions and "advising" or "co-advising" roles played by faculty. One PI is a co-advisor for multiple students, and those trainees interact in his laboratory and are thus also learning from each other. It is also common that projects require students to form an interdisciplinary dissertation committee.

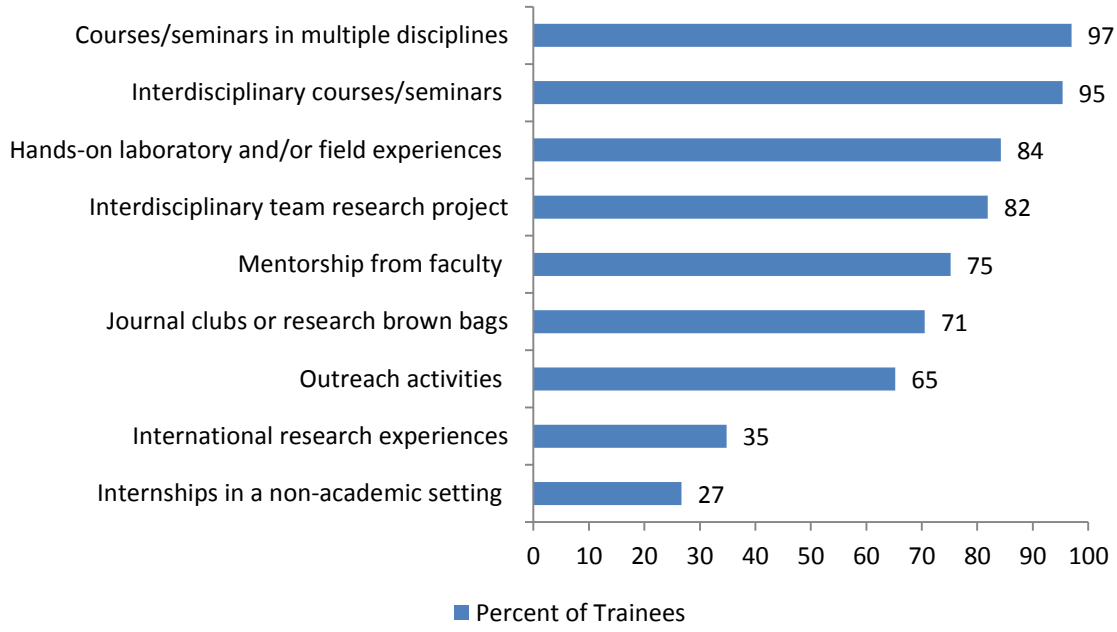
Outreach Activities

Two-thirds of the PI respondents oversee IGERT projects that engage in some outreach to K-12 schools and/or the general public. According to PIs, about a quarter of IGERT projects in the study sample work directly with schools in their respective substantive areas, and often make presentations to K-12 classrooms. Three projects work with K-12 teachers to boost teachers' skills and provide professional development opportunities. Outreach to the general public mostly occurs during community events that take place on campus, during which departments or research groups showcase their work. Another opportunity to engage with the community occurs in those projects that have field experiences. Trainees may aid in community presentations on the research problem facing that region, including steps that communities themselves can take to solve the problem.

Trainee Perspectives: Participation in IGERT Activities

Information on trainees' participation in the IGERT activities was gathered directly from trainees via surveys. Exhibit 4.2 illustrates the pattern of trainees' participation in the various IGERT offerings. Although trainees participated in some activities more frequently than others, at least one-quarter of trainees reported that they participated in each of the nine (IGERT) activities offered by their respective projects.

Exhibit 4.2. IGERT Activities in Which Trainees Participated



Notes:

431 trainees were asked these questions. No (0) trainees did not answer these questions.

Exhibit reads: Ninety-seven percent of trainees reported that they had participated in courses/seminars in multiple disciplines.

Source: IGERT Trainee Survey, Item C1

Survey results indicate that the vast majority of trainees participated in courses/seminars in multiple disciplines as well as in interdisciplinary courses/seminars (97 and 95 percent, respectively), which is consistent with prior evaluation findings that gaining access to fields outside one's home discipline and having the opportunity to study multiple disciplines in one setting are central to trainee participation (Carney, Chawla, Wiley & Young, 2006). Over four-fifths (84 percent) of trainees reported having laboratory rotations in multiple disciples and/or field experiences in disciplines related to the IGERT project. Many IGERT projects require trainees to complete research projects in multidisciplinary teams. In fact, over four-fifths (82 percent) of trainees reported working on a research project with teams comprised of individuals from multiple disciplines. Three-quarters of the trainees also reported that they had been mentored by faculty outside their home department.

Although the IGERT program solicitation calls for developing and enhancing trainees' international perspectives, only 35 percent reported that they had already had exposure to international research opportunities. Finally, roughly one-quarter (27 percent) reported that they had internships within industry-based, national laboratory or other non-academic settings.

Overall Helpfulness of IGERT Training

Trainees were asked to rate (on a four point scale: not at all helpful, somewhat helpful, helpful, very helpful) the helpfulness of their overall IGERT training in developing their knowledge, skills or abilities in the six competency areas. At least 85 percent of survey respondents reported that IGERT provided them with opportunities to enhance four of the six identified competency areas (Exhibit 4.3).

- Breadth of knowledge and skills across disciplines (86 percent);
- Ability to apply the tools and approaches from different disciplines to their research (86 percent);
- Ability to work on research projects with individuals from disciplines outside their own (88 percent); and
- Experience practicing oral and written communication skills needed to interact with researchers from other disciplines (88 percent).

Since IGERT focuses on interdisciplinary research training, it is not surprising that only six out of ten trainees reported that their IGERT training helped them gain depth of knowledge in a single discipline.

"My IGERT experience has been wonderful. I have established many collaborations within my field of research, in other fields, and even in nonacademic sectors. For example, I have worked with reporters from NPR, Science, and The History Channel and they have helped me develop new ways to make my research accessible to the public. At the same time, I have been conducting interdisciplinary research with faculty and other students from institutions in the US, Kenya, and South Africa. This has allowed for international experiences that have greatly benefited my own research, and I believe it has been equally beneficial for my international collaborators. Overall, my IGERT experience has served as excellent preparation for all aspects of the scientific career ahead of me."

- IGERT Trainee

"IGERT has, hands down, been the best part of my graduate school experience. As a result, my research interests and abilities have broadened significantly, I have developed a strong professional network of scientists in different disciplines, gained experience conducting international and interdisciplinary research, and my communication skills have improved 100%. I recommend this program to every graduate student who dreams of being an effective communicator and has interests that go beyond one discipline."

- IGERT Trainee

Exhibit 4.3. Overall Helpfulness of IGERT Training Activities in Developing Specific Interdisciplinary Competencies: Trainee Ratings

Interdisciplinary Competency	Helpful/Very Helpful N (%)
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	381 (88)
Ability to work in a team with individuals trained in different disciplines	378 (88)
Ability to apply the approaches and tools from multiple disciplines to address a research question	372 (86)
Ability to recognize the strengths and weaknesses of multiple disciplines	370 (86)
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	305 (71)
Depth of knowledge in one discipline or field of study	261 (61)

Notes:

Number of trainees who were asked this question=431. No (0) trainees did not answer this question.

Exhibit reads: A total of 381 (88 percent) trainees reported that their IGERT training has been helpful or very helpful in developing their "ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines."

Source: IGERT Trainee Survey, Item C2

Other Skills Enhanced by IGERT Training

Trainees also described other knowledge, skills or abilities they believe IGERT helped develop. The main themes that emerged from these open-ended responses are three-fold: 1) transferable skills (e.g., oral and written communication skills, technical skills, leadership skills, project management, ability to mentor others, time management, etc.); 2) personality traits (e.g., confidence, flexibility, interpersonal skills, open-mindedness to others' point of view, patience, persistence, respect for others, etc.) and 3) an elaboration of a competency already mentioned in the close ended responses: the ability to recognize multi-disciplinary approaches. In addition, a handful of trainees mentioned networking skills (e.g., networking with IGERT faculty, networking with colleagues, peers and mentors outside home discipline, exposure to non-academic experts such as industry and government scientists, etc.).

Transferable Skills

Trainees described how their IGERT experience helped develop and strengthen such technical skills as "social science data collection methods (interviews, surveys, focus groups, etc.)," "a formalized process for conducting a literature review," "programming skills" and "film making." Trainees also acknowledged IGERT's contribution in developing their ability to write proposals, grants, and interdisciplinary scientific publications, including "the ability to write academically across disciplines." A few trainees also mentioned IGERT's role in developing leadership skills that could be applied in leading teams of interdisciplinary researchers or spearheading large-scale outreach events; a handful described IGERT's role in enhancing their project management skills.

Personality Traits

Trainees described certain personality traits (e.g., interpersonal skills, flexibility, an open mind to others' points of view, patience) that they considered important for becoming interdisciplinary scientists. Some examples of what trainees noted include characterizing interpersonal skills as the "ability to navigate group dynamics and how to function in a team doing research," and acknowledging that "patience and trust in your co-workers will improve how they work with you and follow your instructions."

PI and Trainee Perspectives: Activities Used to Develop Interdisciplinary Skills

The activities described above have been used by IGERT PIs and faculty to introduce interdisciplinary concepts in varied settings, and ultimately, to build trainees' interdisciplinary knowledge, skills, and abilities. Across all competency areas, three IGERT activities were described by a majority of PIs as being pivotal in developing trainees' capacity to conduct interdisciplinary research: interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects (see Exhibit 4.1). Even though other activities were considered important in certain projects and for developing specific competencies, fewer PIs describe these activities as central across the study's competency areas. For example, PIs reported that outreach activities represented the activity most often used to develop trainees' capacity to communicate research to laypersons, yet that activity was not mentioned for other competency areas.

The trainee survey data painted a similar picture. A few IGERT activities were consistently reported as helpful or very helpful for developing trainees' interdisciplinary competencies. These activities include courses and seminars in multiple disciplines, interdisciplinary courses, laboratory and field experiences and interdisciplinary team research projects (see Exhibits 4.4. through 4.8). Other activities were less frequently mentioned as being helpful in developing trainees' interdisciplinary research capacity across competency areas. Like the PIs, trainees considered outreach activities as the most helpful type of activity in developing their capacity to communicate research to laypersons (see Exhibit 4.8).

"Through the IGERT training program I have had the opportunity to mentor younger graduate students. A large part of the perspective I have gained from my IGERT training is not only looking forward to all of the opportunities for future research, but also looking back to see how I have personally grown and matured in my graduate career. Drawing on my experiences as an IGERT trainee, I have been able to encourage and educate other students who are just beginning graduate school."

– IGERT Trainee

"I've developed an appreciation for project planning that I didn't originally have. It takes much more time and attention to develop a worthy interdisciplinary project than I thought."

– IGERT Trainee

The text below summarizes how projects utilize the one to two most frequently referenced (by PIs) activities to develop five of the six interdisciplinary competencies,[12] followed by a summary of trainees' observations about how various activities help them develop interdisciplinary skills.

[12] The competency of 'depth of knowledge in one discipline or field of study' is not discussed here, as PIs indicated that IGERT project activities were not designed to develop this skill in trainees; rather, trainees cultivate this in their respective home departments and/or bring this expertise with them to the IGERT project.

PI Reports: Activities to Develop Trainees' Ability to Recognize Strengths and Weaknesses of Multiple Disciplines

Interdisciplinary Courses and Seminars

PIs most frequently referenced the use of interdisciplinary courses and seminars as a mechanism for developing IGERT trainees' ability to recognize strengths and weaknesses of different disciplines. While the formats and structures of these courses are diverse, there was a uniform focus on exposing trainees to a variety of disciplines and disciplinary approaches to broaden trainees' perceptions and understanding of what it means to do interdisciplinary research. Eight PIs described the challenges students face when learning new disciplines—either because of their own academic backgrounds (e.g., three PIs commented on students who did not necessarily arrive with a strong foundation in math or statistics) or because trainees are far outside their interdisciplinary comfort zone. PIs reported that they therefore deliberately organize certain courses to provide disproportionally more exposure to areas with which students are least familiar. In one instance, there were different courses for students whose disciplinary backgrounds varied such that each student would take the course appropriate to his/her own knowledge gap (e.g., the biologist takes a computing-focused course and vice versa). That way, when trainees come back together in future courses, they have greater disciplinary breadth, and can therefore communicate across disciplines more readily.

Part of providing exposure to different disciplines is ensuring that trainees themselves have diverse backgrounds. Eight PIs described their efforts to ensure that the student composition within these courses is heterogeneous. This diversity alone is beneficial as students not only learn from the faculty but also from each other through group discussion, trainee presentations, and class projects that are most often team-based. Another common hallmark of the interdisciplinary course/seminar is the use of invited speakers, which range from current IGERT faculty, resident or visiting scholars from disciplines related to the IGERT theme, industry professionals, and NGO community members. One short seminar series focused around the project's theme invited national and international speakers from academe, policy, industry, and business to provide trainees with a breadth of perspectives. In two cases, when a particular seminar was open to the entire campus community, IGERT students had their own chance to meet with the visitor for more informal and behind the scenes discussions, such as how a given idea was generated or what was tried that didn't work.

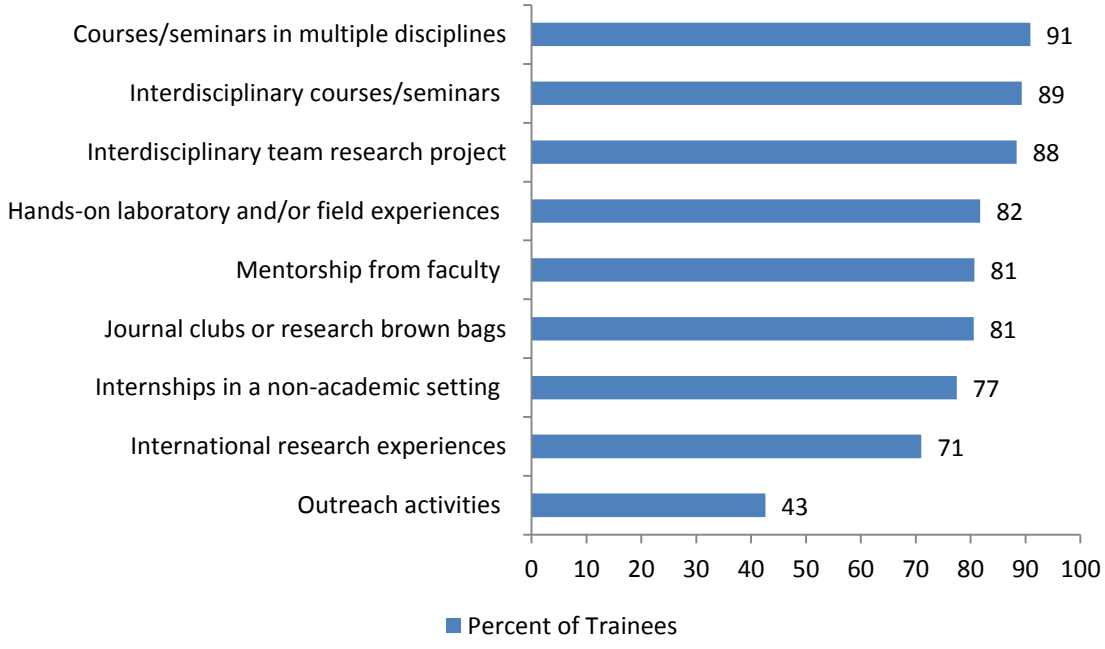
Laboratory and Field Experiences

Seven IGERT projects aligned field research requirements with recognizing interdisciplinary applications; other PIs reported that lab and field experiences are used to develop trainees' ability to recognize the strengths and weaknesses of multiple disciplines. For one project, in particular, the PI noted how IGERT faculty press students to examine evidence, ask questions, and propose interdisciplinary approaches to the research problems uncovered in the field. According to the PI, this exercise is much harder to actualize in a classroom setting. For such PIs, field experiences are tied to the need to solve real-world, pressing research problems, thus requiring trainees to construct meaning across disciplines in a timely manner. Trainees in less structured settings such as interdisciplinary laboratory meetings, while not always pressed as hard to construct solutions to a research problem, are nonetheless exposed to differing research approaches on a regular basis. Over time, this contributes to their understanding of the attributes and challenges of utilizing different disciplines.

Trainee Reports: Activities Helpful for Developing Ability to Recognize the Strengths and Weaknesses of Multiple Disciplines

Trainees' responses were generally consistent with PIs' reports about the activities that contributed to this competency; they too considered interdisciplinary courses and seminars (89 percent) and laboratory/field experiences (82 percent) as helpful or very helpful to their process of recognizing the strengths and weaknesses of multiple disciplines to address a research problem. A large majority of trainees also indicated that courses in multiple disciplines, mentorship from faculty from departments outside one's own, and journal clubs or research brown bags were helpful/very helpful (91, 82, 81 and 81 percent respectively). About two-fifths (43 percent) of trainees who participated in outreach activities considered them beneficial for enhancing this competency area. (See Exhibit 4.4)

Exhibit 4.4. Trainees' Assessments of the Helpfulness of IGERT Activities in Developing Their Ability to Recognize the Strengths and Weaknesses of Multiple Disciplines



Notes:
Trainees received these items only if they had reported that their overall IGERT training had been helpful or very helpful in developing this competency area. The N varies with each item as trainees were asked about the helpfulness of a particular activity only if they had participated in that activity.
Courses/seminars in multiple disciplines: N=362, Missing =1; Interdisciplinary courses/seminars: N=360, Missing=1; Interdisciplinary team research project: N=310, Missing=1; Hands-on laboratory and/or field experiences: N=312, Missing=0; Mentorship from faculty from outside home department: N=295, Missing=0; Journal clubs or research brown bags: N=263, Missing=1; Internships in a nonacademic setting: N=102, Missing=0; International research experiences: N=131, Missing=0; Outreach activities: N=244, Missing=0.
Exhibit reads: Of the trainees who had participated in courses/seminars in multiple disciplines, 91% considered this activity as helpful or very helpful in developing their ability to recognize the strengths and weaknesses of multiple disciplines.
Source: IGERT trainee survey, Item C4.

Open-ended comments provided by trainees offer more insights on specific IGERT activities that they believe help them recognize the strengths and weaknesses of different disciplines. The main theme, represented by one-third of such open-ended responses, was the value of interactions with other students. Many responses described the benefit of informal student interactions.

Although trainees were asked to rate the helpfulness of interdisciplinary courses and seminars, some reiterated their importance in open-ended comments:

> *"It helps when one department has a guest speaker and advertises it across departments. The broader the audience, the broader the questions and discussion afterwards, and thus we discover what some strengths and weaknesses might be for each discipline represented."*

> *"The [program name] program here allows us to see two related research talks from two different disciplines once every couple of months. This really helps us see how a similar problem is approached in two different disciplines, and how each presenter approaches questions from the audience, which is also interdisciplinary."*

"Sharing office space with other IGERT students was incredibly helpful. We discussed our work and how the multiple disciplines we came from differed. Those discussions of theory and epistemology with students were more helpful than formal courses."

- IGERT Trainee

Conversations with other graduate students and faculty advisors. Often, these are informal (… at potlucks) but they are some of the most useful (and honest) discussions."

- IGERT Trainee

"Through my IGERT program I've had the opportunity to get guidance and perspective on a range of topics outside my discipline that was outside of the scope of course or project interactions, just as a matter of increased opportunities for informal communication with individuals from a diverse scientific community."

- IGERT Trainee

Others reemphasized the value of attending laboratory meetings with students in other disciplines:

> *"Working in an interdisciplinary lab and then working in a molecular biology lab helped me see some of the strengths and weaknesses of each. The interdisciplinary lab is very reliant on others to provide them with the constructs from the molecular lab, and is isolated from the molecular lab. The interdisciplinary lab also is working on biological work which isolates it from the typical research of the department."*

One trainee provided a rich description of a number of activities that helped broaden his perspective across disciplines (emphasis added **in bold**):

> *"The IGERT Workshop, an **interdisciplinary team project** with five graduate students from different disciplines working on a project for a client outside of academia, has been most helpful for this. We also are required to perform a one semester **internship with a faculty member in a different department**, which was helpful for this. Finally, interaction with other students in **symposia and colloquiums** has broadened my perspective on the strengths and weaknesses of multiple disciplines."*

PI Reports: Activities to Develop Trainees' Ability to Apply the Approaches and Tools from Multiple Disciplines to Address a Research Problem

Interdisciplinary Courses and Seminars

Interdisciplinary courses and seminars are utilized by the majority of projects to promote the application of approaches and tools in interdisciplinary research settings. Through interdisciplinary seminars, trainees gain exposure to the literature of multiple disciplines, engage in lively discussions on disciplinary connectivity, and often have opportunities to explore portions of what they're learning in a hands-on setting. Course sequences are often compartmentalized such that trainees experienced repeated exposure and opportunity to use interdisciplinary applications—a strategy discussed by 14 PIs. Two IGERT projects offer a course sequence intentionally built around a large research problem that trainees attempt to solve. One project's sequence is centered around research on environmental change. Course modules include scientific content as well as the public and economic impacts of environmental change, including analysis of human behavior that promotes or dissuades environmental sustainability. Another module is a communications course in which students prepare to communicate findings to the local community.

> **"When we have engineers and scientists and philosophers and Native American studies people in the same class, they learn to communicate with each other and develop a shared vocabulary and a dialogue develops around core concepts."**
>
> ***- IGERT PI***

As is the case for other competencies, PIs noted that the use of student presentations in these seminars had a powerful influence on trainees' understanding of how different methodologies–whether alone or in conjunction with one another—can be applied to solve a research problem. Presentations by faculty and other invited speakers had a similar effect in that students become comfortable engaging on a variety of topics from a multitude of disciplinary perspectives, even when such approaches are completely new concepts for trainees. According to one PI, this high level of interaction with faculty also helps trainees become comfortable questioning faculty on a given approach, which is an important skill, since the students are often seeing material for the very first time and need to feel free to ask questions.

Laboratory and Field Experiences

Laboratory or field experiences were the most commonly cited way of helping trainees understand the application of tools from multiple disciplines when attempting to address a research problem. No matter the format (e.g., lab course, lab rotation, field experiment), PIs emphasized the importance of exposure to different types of data, research methods, and research tools so that when trainees are themselves conceptualizing interdisciplinary research, they have a clearer sense of how different fields can be applied in solving a research problem.

> **"[Trainees] do multiple [lab] rotations… they are weaving the fabric of their project by using different threads from different labs."**
>
> ***- IGERT PI***

Generally, trainees are expected to attend lab meetings and learn the culture of the lab. In one IGERT project, trainees are assigned faculty "co-advisors" across several labs, each of which is perceived as a distinct experience which will ultimately contribute to a larger research project constructed by the trainee. By design, the co-advisors do not work together themselves, but leave it up to the trainee to make the appropriate methodological connections with individual guidance from each faculty member. In another example, it is through the lab rotations that trainees ultimately identify and select their permanent research advisor.

Several IGERT PIs reported using interdisciplinary field experiences – both near and far from campus – specifically to develop trainees' abilities to apply approaches and tools from multiple disciplines. These PIs described an on-the-ground experience designed to help trainees understand how research tools and methods are applied in real-world settings. Since multiple faculty members take part and lead these experiences, students can see how each may approach a problem differently, and can witness back-and-forth discussions between faculty. It is through such field experiences that students are also exposed to the public policy dimension of their IGERT theme (if applicable). Some projects build in policy-specific content and visit policymakers in field locations or meet with policy officials in the state or region.

Trainee Reports: Activities Helpful for Developing Ability to Apply the Approaches and Tools from Multiple Disciplines to Address a Research Problem

Over four-fifths of trainees (86 percent) considered interdisciplinary courses/seminars and hands-on laboratory/field experiences helpful or very helpful in developing their ability to apply the approaches and tools from multiple disciplines (Exhibit 4.5). When asked to comment about other IGERT training activities that had been helpful to developing this competency area, one trainee elaborated on the utility of hands-on laboratory experiences, "the IGERT lab modules that are offered by our program have been extremely helpful in developing my ability to apply the approaches and tools from multiple disciplines to address a research question." Another trainee commented, "Lab modules offered over the summer allow us to explore techniques used in other disciplines. Sometimes, these techniques are found to be applicable to the student's own research project. Even if the technique is not applicable, it introduces the student to new terminology and gives them an appreciation for work in a field outside of their own."

"We have something called [name of workshop] workshop where a student presents research that is in-progress and members from the [STEM discipline] community comment and make suggestions on how to improve the research. These workshops help students focus their projects and foster collaborations."

- IGERT Trainee

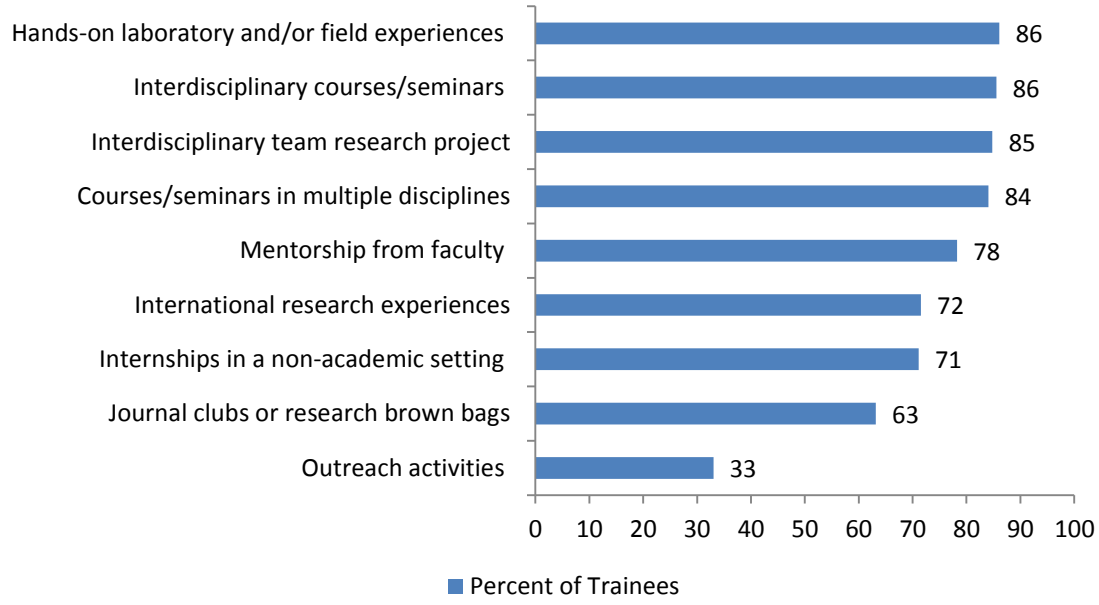
"**Yes, the annual [name of workshop] workshops have been helpful in developing my ability to apply the tools from multiple disciplines to address the research question in [sic.] my own discipline. Particularly, this past winter storm I participated in [an] Eye-tracking method workshop where I was able to learn to use eye trackers to study sentence processing. I plan to apply this tool to study my own research question of how bilingual speakers process sentences in their second language."**

- IGERT Trainee

"**At the beginning of my graduate career I had a limited knowledge of many fields of study. Through the [IGERT Name] training I have been able to obtain more information from each field and use such information in synergy to do my studies. The synergistic approach has allowed me to integrate the fields [of] cancer biology, developmental biology, chemistry, biochemistry, metabolic flux and cellular engineering in my study. I have developed and employed techniques that differ greatly from traditional formats and that have provided data unobtainable by classic means."**

- IGERT Trainee

Exhibit 4.5. Helpfulness of IGERT Activities in Developing Trainees' Ability to Apply the Approaches and Tools from Multiple Disciplines



Notes:

Trainees received these items only if they had reported that their overall IGERT training had been helpful or very helpful in developing this competency area. The N varies with each item as trainees were asked about the helpfulness of a particular activity only if they had participated in that activity.

Hands-on laboratory and/or field experiences: N=317, Missing=0; Interdisciplinary courses/seminars: N=360, Missing=0; Journal clubs or research brown bags: N=269, Missing=0; Courses/seminars in multiple disciplines: N=364, Missing =0; International research experiences: N=130, Missing=0; Internships in a nonacademic setting: N=104, Missing=0; Mentorship from faculty from outside home department: N=294, Missing=0; Interdisciplinary team research project: N=316, Missing=0; Outreach activities: N=242, Missing=0.

Exhibit reads: Of the trainees who had participated in hands-on laboratory and/or field experiences, 86% considered this activity as helpful or very helpful in developing their ability to apply the approaches and tools from multiple disciplines.

Source: IGERT trainee survey, Item C5.

The usefulness of interdisciplinary seminars in fostering the ability to apply different disciplinary approaches was further underscored by a number of trainees who mentioned a variety of courses and seminars that helped develop their ability to apply the tools from different disciplines. For example, trainees mentioned such IGERT-required courses as: "Social Network Analysis," "research methods courses that integrate multiple disciplines," "programming courses and workshops," and an "…IGERT specific methods course focused on advanced microscopy and analytical methods..."

Some trainees provided detailed descriptions of activities that helped them apply the tools from other disciplines in their research (see textbox examples). A handful of trainees mentioned the value of conference attendance and the support from IGERT to attend conferences.

PI Reports: Activities to Develop Trainees' Ability to Work in a Team with Individuals Trained in Different Disciplines

Interdisciplinary Team Research

Perhaps not surprisingly, IGERT-facilitated team research projects are the most commonly used activity to build team skills. PIs emphasized the value of experiences that allow trainees to bring their respective

skill sets–as members of different academic communities–to bear within a team attempting to solve a research problem too large for one individual student or one disciplinary perspective. PIs also noted that a large part of a given team's success relies on effective communication, the ability of students to assist one another when challenges arise, and the organizational and leadership skills of individual trainees.

Specific to this competency, 15 PIs described the formation of trainee research teams as defined IGERT activities. Some students are part of teams for a brief time, such as during lab rotations or modules, while others stay with their team the better part of a year or longer. As students move through their graduate programs and through IGERT, lab and field experiences become more common and intensive while continuing to vary in structure. For example, one IGERT project tackles a large, overarching research problem through the use of several small cross-departmental teams of one to two trainees and one faculty member. Another example is the relatively small, tight-knit faculty-student teams that work in the field, often during the summer months. Also emergent are all-student teams, which form as trainees become more knowledgeable and sophisticated in their interdisciplinary understanding.

Interdisciplinary Courses and Seminars

Thirteen PIs reported that interdisciplinary courses and seminars represent a core mechanism for developing team building skills for interdisciplinary research. While there are IGERT seminars and workshops explicitly devoted to the development of team skills, PIs described using video projects, risk assessments, case studies, and research projects as part of IGERT coursework. Five IGERT projects that integrate lab and field experiences into interdisciplinary seminars provide a distinct opportunity to build teams that carry across the lab and classroom settings. Classroom and laboratory team time complement one another as trainees often present what they do in the lab to the trainee group at large. Two PIs specifically noted that they incorporate team projects early on in the course sequence so that students become accustomed to working in teams as soon as possible.

Trainee Reports: Activities Helpful for Developing Ability to Work in a Team with Individuals Trained in Different Disciplines

Ninety-three percent of trainees reported that participating in research projects with an interdisciplinary team helped them develop essential multi-disciplinary team-work skills (Exhibit 4.6)—a finding consistent with information provided by PIs. A previous evaluation of the IGERT program found that IGERT students are twice as likely as non-IGERT students to have worked on research projects with students with different disciplinary backgrounds (Carney et al., 2006).

Hands-on laboratory and field experiences, international research experiences, interdisciplinary courses and seminars, and mentorship from faculty from other disciplines all involve formal and informal interactions with faculty and students with diverse disciplinary backgrounds. At least four-fifths of survey respondents rated the aforementioned activities as helpful or very helpful to developing skills to work in a multi-disciplinary team. Trainees described field trips that helped to develop stronger relationships, field-based experiences that contributed to better understanding of different points of view, and the importance of learning to adapt to team members' different working styles and strengths. Another trainee described a group project and how participation was useful in helping develop this competency area.

> **"The summer short courses have been very helpful in working with individuals in different disciplines. The engineers are better at math, and the life scientists are better at the wet bench work. Having both people on a team really helps a lot with assembling results and minimizing bottlenecks in presenting the data."**
>
> ***- IGERT Trainee***

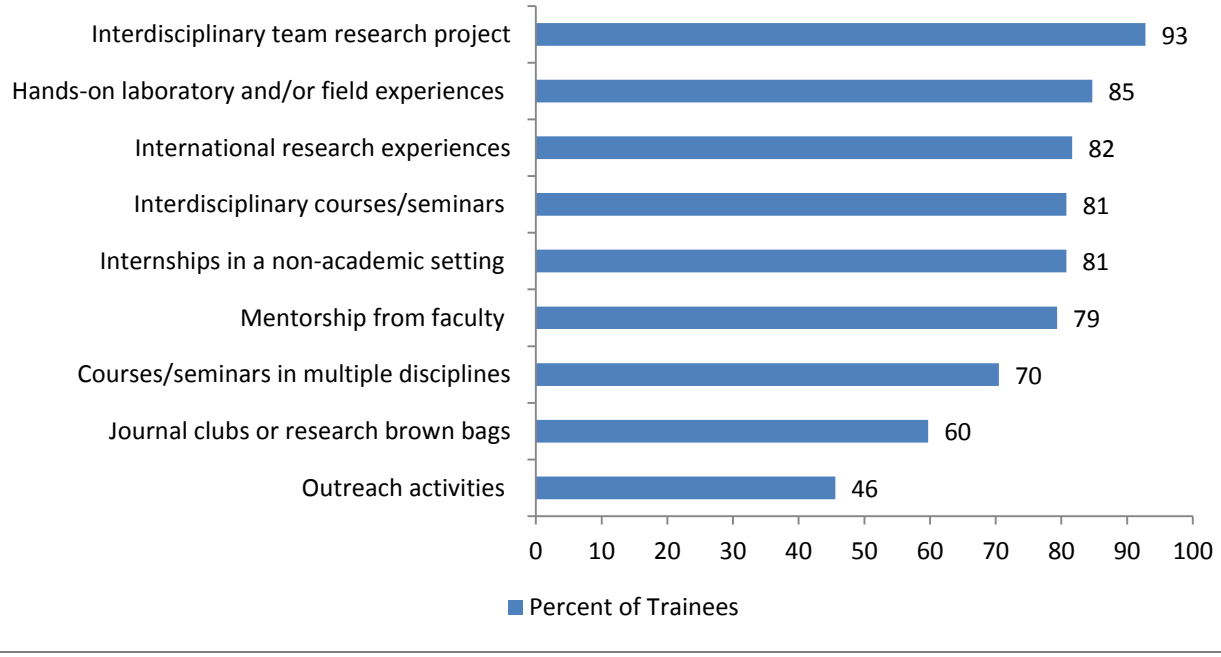
Others emphasized the value of team-teaching, presenting at conferences with others from disciplines outside their own, and working on joint publications with other IGERT trainees. One trainee elucidated how participating in various team-oriented IGERT activities helped her develop into a "technical interpreter" which greatly enhanced her team-work skills.

Explaining why the group project was a good experience:

"We are all forced to work together and combine our approaches to a problem. There was lots of head butting and meltdowns at times, but ultimately it helped me think about the way one acts as a constructive member of a team, when the team is made up of people who bring very different things to the table."

- IGERT Trainee

Exhibit 4.6. Helpfulness of IGERT Activities in Developing Trainees' Ability to Work in an Interdisciplinary Team



Notes:
Trainees received these items only if they had reported that their overall IGERT training had been helpful or very helpful in developing this competency area. The N varies with each item as trainees were asked about the helpfulness of a particular activity only if they had participated in that activity.
Interdisciplinary team research project: N=320, Missing=0; Hands-on laboratory and/or field experiences: N=321, Missing=0; International research experiences: N=137, Missing=0; Interdisciplinary courses/seminars: N=365, Missing=0; Internships in a nonacademic setting: N=110, Missing=0; Mentorship from faculty from outside home department: N=296, Missing=0; Courses/seminars in multiple disciplines: N=370, Missing =0; Journal clubs or research brown bags: N=269, Missing=0; Outreach activities: N=249, Missing=0.
Exhibit reads: Of the trainees who had participated in an interdisciplinary team research project, 93% considered this activity as helpful or very helpful in developing their ability to work in an interdisciplinary team.
Source: IGERT trainee survey, Item C6.

PI Reports: Activities to Develop Trainees' Ability to Communicate Research across Disciplines

Interdisciplinary Courses and Seminars

The use of student-to-student and student-to-faculty presentations within interdisciplinary course/seminar settings was by far the most frequently cited mechanism PIs referenced for training IGERT students to

communicate research across disciplines—whether it was to share research findings based in one discipline or share interdisciplinary concepts at large. The content of trainee presentations varied from specific research areas to experimental techniques to analytic methods. It seemed the most important thing was to get trainees talking and comfortable with interdisciplinary material and audiences. PIs also noted that students not only become accustomed to talking about interdisciplinarity but also learn how to *listen*, which allowed trainees to form critical observations and questions about their own work and the work of others. The ability to properly field such questions during a presentation was also mentioned by several PIs, which again, aids in trainees' grasp of complex research problems and approaches. Additional emphasis was placed on teaching trainees how to present ideas without the use of discipline-specific jargon since the language of science most often varies across academic fields.

In addition to presentations, nine PIs noted course requirements that require students to hone their writing skills with a diverse disciplinary audience in mind. In one IGERT project, trainees were responsible for producing a research blog entry for the audiences of "peer scientist, informed general public, and school children," thus prompting trainees to distinguish how to write about their work when communicating to specific audiences; this exercise also involved group work and a presentation to the class. As in purposely creating class rosters that reflect students' different backgrounds, several PIs noted such diversity is important for strengthening cross-disciplinary communication. Particularly for projects that draw on more than two or three disciplines, allowing students to construct a common language is critical. Because this common language is used during structured activities as well as informal interaction, according to one PI, students begin to realize that not everyone thinks the way they do.

Trainee Reports: Activities Helpful for Developing Ability to Communicate Research across Disciplines

Nearly nine of 10 trainees consider interdisciplinary team research projects as helpful or very helpful in developing their ability to communicate with researchers from disciplines outside their home discipline (Exhibit 4.7). Consistent with PI reports, 85 percent of trainees also indicated that interdisciplinary courses and seminars contributed to this competency.

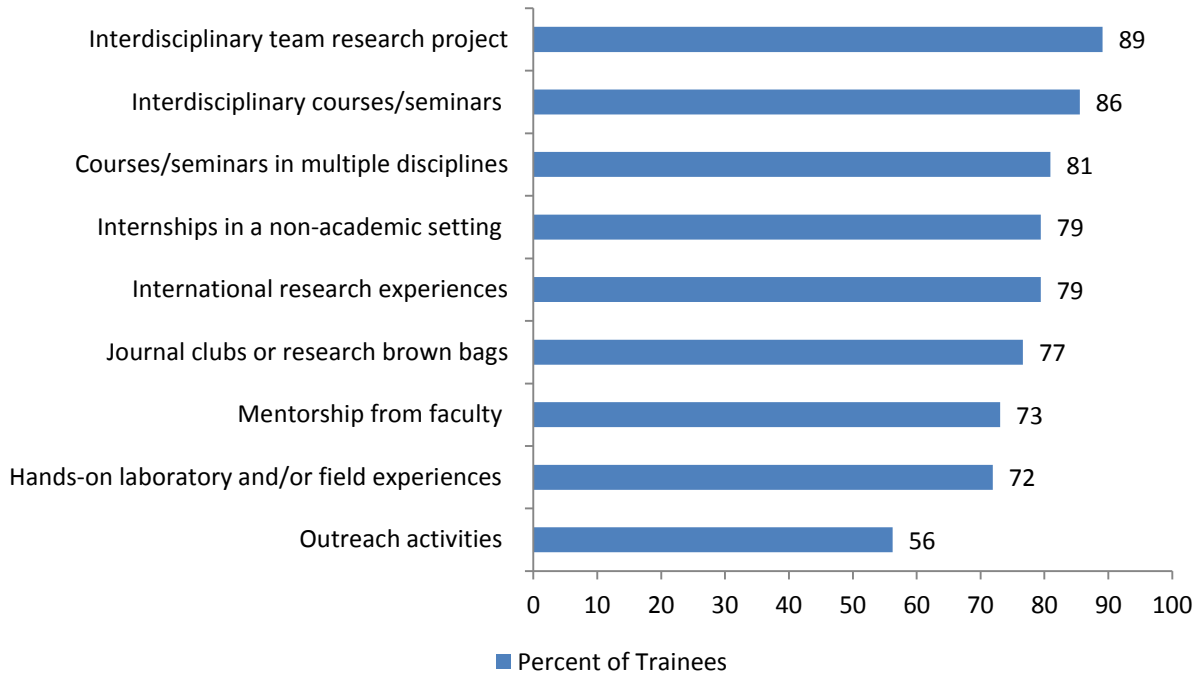
"Communication is key. The most helpful aspect of the IGERT to me was the various presentations we made to our peers and different audiences. It's an important skill to be able to convey your ideas to people less familiar with the subject than you, and it's an eye-opening experience to receive feedback from people who aren't intimate with your work."

- IGERT Trainee

" … In one of our IGERT specific courses we presented our final work from two years of multi-disciplinary research to [the IGERT external visiting] committee. This helped me develop a specific type of presenting skill required for communicating competency. These types of presentations have become common though-out [sic] my doctoral program with oral comprehensive exams and such. But its [sic] more than that, I know that I can step outside of my traditional engineering arena and effectively communicate proficiency in multiple fields (such as microbiology and geochemistry) to the respective experts."

- IGERT Trainee

Exhibit 4.7. Helpfulness of IGERT Activities in Developing Trainees' Ability to Communicate to Researchers from Different Disciplines



Notes:
Trainees were asked these items only if they had reported that their overall IGERT training had been helpful or very helpful in developing this competency area. The N varies with each item as trainees were asked about the helpfulness of a particular activity only if they had participated in that activity.

Interdisciplinary team research project: N=322, Missing=0; Interdisciplinary courses/seminars: N=367, Missing=0; Courses/seminars in multiple disciplines: N=373, Missing =0; International research experiences: N=137, Missing=0; Internships in a nonacademic setting: N=108, Missing=0; Journal clubs or research brown bags: N=275, Missing=0; Mentorship from faculty from outside home department: N=298, Missing=0; Hands-on laboratory and/or field experiences: N=332, Missing=0; Outreach activities: N=257, Missing=0.
Exhibit reads: Of the trainees who had participated in an interdisciplinary team research project, 89% considered this activity as helpful or very helpful in developing their ability to communicate to researchers from different disciplines.
Source: IGERT trainee survey, Item C7.

Trainees' open-ended comments described how IGERT allowed them to develop and strengthen their oral communication skills by providing them opportunities to present their research at professional conferences, national meetings, and other forums. Their responses suggest that some trainees have had opportunities they otherwise may not have had to present their work at regional and national meetings as a result of the IGERT support. Others emphasized how IGERT paved the way to present work to other students from disciplines outside their own through group research projects, IGERT lunches and seminars, and journal clubs and workshops. Some trainees mentioned attending proposal writing workshops as part of their IGERT experience that helped strengthen their writing skills.

PI Reports: Activities to Develop Trainees' Ability to Communicate about Interdisciplinary Research to Non-academic Audiences

Outreach Activities

Of the 22 PIs whose projects provide outreach activities, nine involve K-12 audiences, chiefly teachers and students. In one IGERT project, trainees work with local schools to develop scientific curricula while another IGERT involves trainees in an NSF-funded program that provides research experience to K-12 teachers over the summer. The latter requires trainees to present material to the teachers and advise them in the laboratory. The teachers are meant to then take that experience and be able to present the work to their own K-12 students. As a result, trainees have the opportunity to hone their communication skills with an informed but not expert audience.

According to PIs, work with K-12 students involves trainee presentations to local classrooms or opportunities where students come to the campus to go on lab tours and see science demonstrations, posters, and other presentations. This often occurs in conjunction with open house events and science festivals on campus, in which case trainees are also presenting to people of all ages, including parents. In one case, IGERT is involved in K-12 summer camps on the university campus; trainees carry out science and engineering demonstrations, including the popular demonstration on how to make liquid nitrogen ice cream. PIs note that some IGERT trainees are better than others at engaging with young audiences; some really get into the experience and come up with their own ideas about what and how to demonstrate in making scientific content accessible to K-12 audiences.

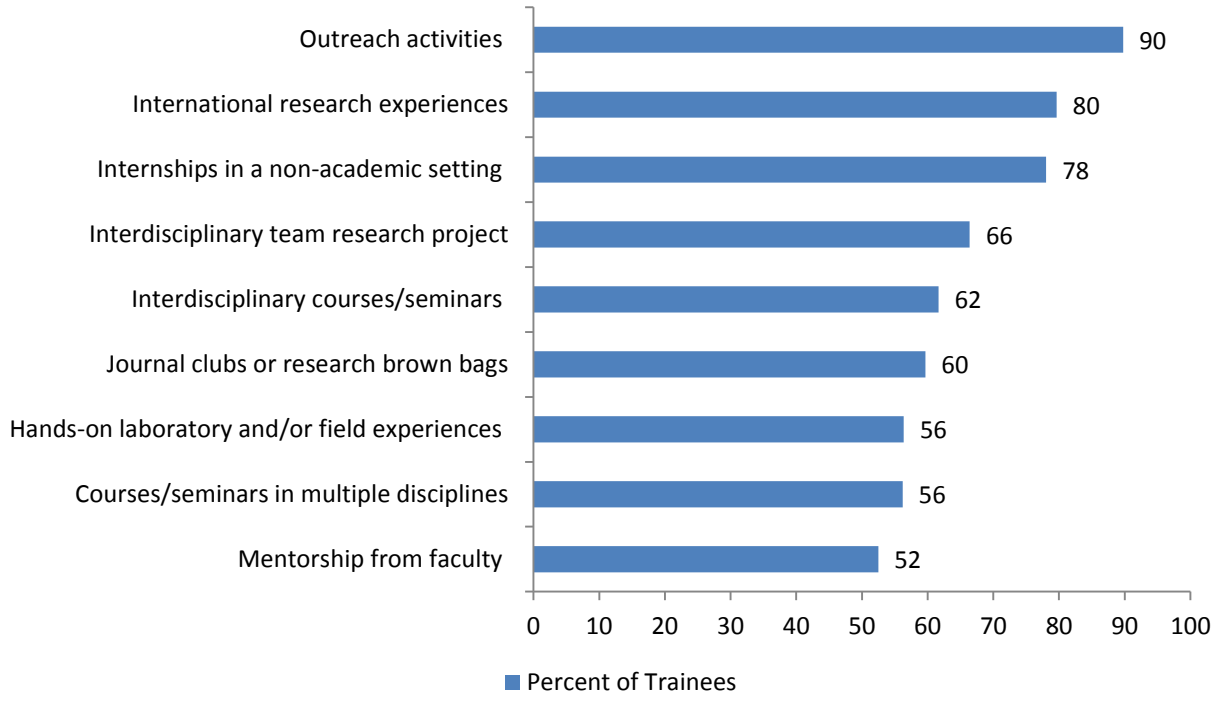
Several IGERT projects, particularly those that do field research or engage in local sustainability efforts, also engage a wider community. For example, some trainees conduct outreach in indigenous communities. A final type of outreach is with the policy community. Three of the projects structure time for trainees in Washington, D.C., where trainees meet with policymakers and other stakeholders to discuss science policy as it relates to the IGERT theme and trainee research. One of these projects meets with a wide variety of science policy stakeholders when in Washington—congressional and committee staff, scientific agency staff, lobbyists, and non-government organizations. Other examples include a science policy internship (not necessarily in Washington) and outreach to local policy officials in field research destinations.

Trainee Reports: Activities Helpful for Developing Ability to Communicate about Interdisciplinary Research to Non-academic Audiences

Trainees' perceptions were similar to those of PIs; among trainees who engaged in outreach activities to K-12 students, teachers or the general public, nearly nine of 10 trainees considered these activities to be helpful/very helpful in developing their ability to communicate research to laypersons (Exhibit 4.8).

> **Through the IGERT program, I have given many talks explaining my research to a broad audience, including industry and government scientists. This has allowed me to practice explaining my research to researchers in other fields of study."**
>
> ***- IGERT Trainee***

Exhibit 4.8. Helpfulness of IGERT Activities in Developing Trainees' Ability to Communicate about Interdisciplinary Research to Laypersons



Notes:
Trainees were asked these items only if they had reported that their overall IGERT training had been helpful or very helpful in developing this competency area. The N varies with each item as trainees were asked about the helpfulness of a particular activity only if they had participated in that activity.

Outreach activities: N=216, Missing=0; International research experiences: N=109, Missing=0; Internships in a nonacademic setting: N=92, Missing=0; Interdisciplinary team research project: N=260, Missing=0; Interdisciplinary courses/seminars: N=293, Missing=0; Journal clubs or research brown bags: N=224, Missing=0; Hands-on laboratory and/or field experiences: N=260, Missing=0; Courses/seminars in multiple disciplines: N=300, Missing =0; Mentorship from faculty from outside home department: N=243, Missing=0.
Exhibit reads: Of the trainees who had participated in outreach activities, 90% considered this activity as helpful or very helpful in developing their ability to communicate about interdisciplinary research to laypersons.
Source: IGERT trainee survey, Item C8.

Trainees elaborated upon their descriptions of outreach activities by highlighting specific examples of presenting to lay audiences, ranging from tribal partners to local community organizations, business leaders, city councils, and students in both general and specialized schools and classrooms. Trainee comments emphasized the value of learning how to engage with different types of audiences and how to present findings in accessible language.

PI Reports: Activities to Develop Trainees' "Other" Skills and Abilities

While not all activities discussed by PIs fall neatly into one of the study's nine categories, there are some that warrant attention given their frequency across the six competencies. Such "other" activities were most often one-time or short term events, annual or bi-annual meetings, or informal get-togethers by IGERT community members. A small number of PIs also referenced using poster presentations, publications, and even the dissertation process, as allowing trainees to build knowledge and communicate across disciplinary boundaries, as well as apply multiple disciplines to address a research problem. Several PIs referred to benefits conferred by the NSF IGERT PI meeting, where select trainees are able to present posters and are thus required to learn how to communicate to researchers from other disciplines. The PI meeting also prompted three campuses to conduct trainings in video production—these activities falling in line with the competency of communicating research material to public audiences.

Stand-alone workshops (that were not otherwise classified by PIs as "seminars") were another common way for IGERT projects to train students on communication skills. One IGERT invited a communications specialist to give a short session on how to present one's work. Another IGERT project works with its university's communications center, which helps trainees write popular articles, practice giving an "elevator speech," and present to large audiences. Workshops are also used to facilitate team building. For example, one PI hired an external expert to run a leadership program while another organized a "how to work in teams" workshop. Finally, most projects host annual retreats or symposia where students present their work to one another or the larger IGERT community, and where faculty and guest speakers may also present research. For two campuses, retreats provided an opportunity to bring trainees and faculty from joint IGERT campuses together to share work conducted throughout the year. One IGERT project invites its advisory board to the annual retreat, where students present their year's work to this group and to their peers. Several projects also host distinguished scientific lecturers or guest speakers who train students on discrete skills.

Successes and Challenges: PI Perspectives

Project Implementation Successes

PIs interviewed over the course of this study described a number of success stories. The most common successes across projects have to do with IGERT as a springboard for longer term institutional change and with the creation of a community of scholars amongst both faculty and trainees. Fourteen PIs credited their respective IGERT projects with having created a sense of intellectual community, which has allowed students to come together and do meaningful work. Six PIs credit IGERT for creating new research directions for faculty and improving communication and research collaborations across departmental lines; in one case,

"One of the 'faculty mentors outside of my department' had me write a guest blog for his website…. It was a good experience to write something for a general audience."

- IGERT Trainee

"We were required in our first year to write an article for the popular press. Ours was published in *Live Science*."

- IGERT Trainee

such collaboration prompted submission of two additional grant proposals to conduct interdisciplinary research.

PIs have piloted a number of activities, such as the very popular interdisciplinary seminars and team research projects, which have benefited a larger body of graduate students and faculty, and which have brought visibility to interdisciplinary research. Three PIs described how IGERT, in particular, has attracted students to their institution; two noted that the quality of their student body has strengthened. In another case, the receipt of the IGERT grant was, in the PI's estimation, responsible for the creation of an entire *department*; whereas initially, IGERT funds had supported only a graduate training program with two faculty, over time IGERT helped catalyze a transformation into an established department with over a dozen faculty and an active research portfolio.

Challenges for Trainees

PIs observed that their trainees face a number of challenges, including balancing both the demands of IGERT and trainees' home department/degree requirements, and the challenge of learning new disciplines. The sheer amount of work that IGERT demands was referenced as a challenge by 12 PIs, with six noting the specific challenge of the time commitment/management. One PI referenced the international research opportunity, in particular, as being challenging for students with families or for those who cannot be away from their campus projects for the required four to six months. There were also references to students feeling overwhelmed, stressed, or challenged by having to meet the requirements of both their home department and of IGERT. Nonetheless, there were no mentions of trainees leaving IGERT due to the workload (although some left for other reasons).

Another challenge, raised by eight PIs, focused on the need for trainees to learn new disciplines such that they are able to engage effectively in interdisciplinary research projects. This seemed especially challenging for students in those IGERT projects that incorporated engineering or advanced mathematics or statistics—some students simply did not have the academic background that prepared them for graduate level work in these disciplines. One PI cited the difficulty faced by his STEM students taking graduate level public policy coursework, especially given the very different way that policy students conduct research and write papers.

Project Implementation Challenges

Many of the implementation challenges named by PIs are unique to individual IGERTs, yet there are emergent trends across projects. First, maintaining faculty buy-in was presented as a challenge by eight PIs. For example, PIs reported difficulties engaging students' home departmental advisors and ensuring that advisors see the value and relevance of the IGERT project and the activities in which students participate. Perhaps related, there is also the challenge of the sheer workload and time commitment that IGERT involvement demands—on the part of PIs, faculty, and trainees alike. Regarding faculty, in particular, five PIs referenced the time burden of teaching IGERT courses or seminars on top of an already full teaching load as campuses won't necessarily offer course release time for IGERT teaching responsibilities. Beyond making time for teaching, several PIs also noted the time it takes to just get constituents together, especially when working across departmental lines and packed schedules.

Another set of challenges concerns funding of both trainees and sustainability of the IGERT project at large. Three PIs noted that the $30,000 IGERT stipend is becoming less competitive in its purchasing power (especially at private institutions), while two others noted the challenge of ensuring funding at this level after the IGERT experience is over. One PI addresses the latter challenge by requiring a given student's home department to provide, in writing, a guarantee of funding for non-IGERT years before accepting the student into the project.

Another concern of PIs is how to sustain IGERT beyond the NSF funding period. Three PIs reported that certain aspects of the IGERT project have been institutionalized, but there is otherwise worry that the activities won't be continued after funding runs out. One PI noted that faculty members are becoming less engaged as the grant end date nears.

A final challenge expressed by six PIs is trainee recruitment into the IGERT project. On the whole, prospective IGERT trainees are some of the most desirable candidates for graduate study. As such, potential trainees often have a host of other options and may be "lured away," as one PI put it, by other opportunities; especially on some of the more selective campuses. On the other hand, more than one PI also noted that it is tough to find highly qualified U.S. citizens in STEM fields given the dominance of foreign born graduate students. One program had a particularly hard time recruiting qualified students within the window provided by NSF (between receiving the grant and bringing on IGERT trainees) while two others are working to adapt to their respective challenges of location and size.

PI Recommendations for the IGERT Program

Of the 39 PIs interviewed, 30 made distinct recommendations for program improvement with most focusing on what they could do locally to improve their IGERT project. While there were thus few common recommendations across interviewees, some themes emerged around improved assessment, recruitment, and faculty engagement. Six PIs noted the need to improve program assessment as a point of emphasis (i.e., recommendations were made in addition to the already discussed (above) assessment needs). Beyond improvements in assessment at the local level, two PIs were interested in better understanding the broader implications of interdisciplinary research training at large. One PI recommended that NSF take up a more systematic way of distributing assessment findings (such as those reported to NSF by individual PIs via annual and other reports) so that PIs can network and learn from other PIs/projects. Related to project assessment, another PI suggested that NSF develop a library of interdisciplinary training evaluation tools that PIs could access and use. Four PIs would like to see their respective projects do a better job at recruiting potential students. Two PIs specifically noted the narrow window between the time that campuses are awarded funds and the time that projects award individual students, making recruiting talented students interested in interdisciplinary research especially difficult for departments with small applicant pools. One PI noted the need to improve the recruitment of underrepresented minority students while another is looking to build better geographic representation of incoming cohorts. Four PIs discussed the need to improve faculty engagement in their respective IGERT projects, while two others noted the need for university administration to better recognize the work that goes into cross-departmental projects like IGERT, and thus improve upon the support of faculty and departments that pursue such projects. One PI stated, "If we are going to find a way to institutionalize these new interdisciplinary approaches to programs, we're going to have to reorganize how one rewards this effort across departments."

Trainee Perspectives: Confidence and Challenges

Confidence Levels, by Competency

Trainees were asked to rate their level of confidence in the six competencies on a four point scale (not at all confident, somewhat confident, confident, and very confident). Overall, trainees were confident or very confident in their preparedness as interdisciplinary scientists. A substantial proportion of trainees (from 71 to 94 percent) reported that they were confident or very confident across the six skill areas that facilitate conducting interdisciplinary research (Exhibit 4.9).

"The IGERT training helped me to get out of my comfort zone and learn about how interdisciplinary research is important as a new model for scientific research, thus giving me an understanding of life cycle analysis, economics, policy and conversion technologies. My public speaking has improved as a result of the IGERT program and I developed more confidence in discussing bioenergy related topics and explaining how my individual research goes into the larger picture of bioenergy research. In addition, my courses and rotations have improved my critical thinking ability and ability to analyze data."

- IGERT Trainee

A majority of trainees reported that they were confident or very confident in their ability to work in an interdisciplinary team (94 percent) and communicate to researchers trained in disciplines other than their own (90 percent). Relatively fewer trainees were confident or very confident in their ability to recognize the strengths and weakness of other disciplines (78 percent) and apply the approaches and tools from multiple disciplines (71 percent).

Exhibit 4.9. Trainees' Confidence in Their Interdisciplinary Competencies

Interdisciplinary Competency	Confident/Very Confident
	N (%)
Ability to work in a team with individuals trained in different disciplines	404 (94)
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	383 (90)
Depth of knowledge in one discipline or field of study	354 (82)
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	348 (81)
Ability to recognize the strengths and weaknesses of multiple disciplines	335 (78)
Ability to apply the approaches and tools from multiple disciplines to address a research question	306 (71)

Notes:
Interdisciplinary team work: N=430, Missing=1; Communicate research to academic researchers: N=429, Missing=2; Depth of knowledge in one discipline: N=431, Missing =0; Communicate research to laypersons: N=431, Missing=0; Recognize strengths and weaknesses of multiple disciplines: N=430, Missing=1; Apply approaches from multiple disciplines: N=430, Missing=1.
Exhibit reads: A total of 404 (94 percent) trainees reported that they were confident or very confident in their ability to work in a team with individuals trained in different disciplines.

Source: IGERT Trainee Survey, Item B8

We examined trainees' survey responses to learn whether there are any meaningful patterns among such subgroups as gender and expected Ph.D. completion date.[13] There are no consistent patterns or notable differences between trainees by gender. There are modest differences in trainees' responses, however, according to their anticipated graduation date. Specifically, trainees who expected to complete their Ph.D. degree program in 2012 or sooner (according to DMS data) reported having more confidence in their skills and had participated in a higher number and type of IGERT activities.

According to the DMS data, a little over one-third of trainees (32 percent) expected to complete their Ph.D. degree program in 2012 or earlier, and nearly one-fifth (18 percent) were in the initial years of their graduate education. A higher proportion of trainees who expected to complete their Ph.D. program by 2012 reported that they were confident or very confident in five of the six identified competencies than respondents in the initial years of their graduate education (see Exhibit 4.10).

[13] The study team also explored the possibility of creating subgroups based on broad disciplinary affiliations, but given the heterogeneity of trainees' self-reported disciplinary affiliations, was not able to create meaningful subgroups on that dimension.

Exhibit 4.10. Trainees' Confidence in Interdisciplinary Competencies, by Expected Ph.D. Completion Date

Interdisciplinary Competency	2 or fewer years in graduate school	Expected Ph.D. Completion in 2012 or earlier
	Confident/Very Confident	
	N (%)	N (%)
Depth of knowledge in one discipline or field of study	56 (72)	123 (90)
Ability to recognize the strengths and weaknesses of multiple disciplines	58 (75)	111 (81)
Ability to apply the approaches and tools from multiple disciplines to address a research question	54 (70)	107 (78)
Ability to work in a team with individuals trained in different disciplines	69 (88)	131 (96)
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	66 (85)	122 (90)
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	66 (85)	116 (85)

Notes:

Years in graduate school 2 years or less: N=78 trainees; Number of missing responses to individual questions ranged from 0 to 1.

Expected Ph.D. Completion in 2012 or earlier: N=137 trainees; Number of missing responses to individual questions ranged from 0 to 1.

Exhibit reads: A total of 56 (72 percent) trainees who were in graduate school for 2 years or less reported that they were confident or very confident in their depth of knowledge in one discipline or field of study.

Source: IGERT Trainee Survey, Item B8

It may be obvious that more advanced students had had more time to participate in different activities; those students who had been in their doctoral programs for four or more years (and who indicated that they planned to graduate by 2012) reported higher frequencies of participation in various IGERT activities than those trainees in their first or second year of graduate study. Some of these activities included hands-on laboratory and/or field experiences in disciplines related to trainees' respective IGERT projects (88 and 78 percent, respectively, for the sooner-to-graduate and newer graduate students), journal clubs or research brown bags (78 and 56 percent, respectively), outreach activities (76 and 56 percent, respectively), and internships in non-academic settings (35 percent and 21 percent, respectively).

Challenges Faced

Trainees were asked to rate the extent to which they experienced specific IGERT-related challenges on a three-point scale (not at all, somewhat, a great deal). Additionally, trainees were asked to comment about the most challenging aspect of their IGERT participation in an open-ended question.

Exhibit 4.11: Challenges Faced as a Result of IGERT: Trainee Perspectives

Challenges of IGERT	Somewhat	A Great Deal
	N (%)	N (%)
Difficulty balancing demands of IGERT versus my degree program	200 (47)	73 (17)
An increased workload compared with peers who are not IGERT trainees	217 (51)	120 (28)
Concern about my participation in IGERT from students or faculty in my primary discipline	89 (21)	40 (9)
Frustration trying to communicate with students from other primary disciplines	100 (23)	24 (6)

Notes:

Number of trainees who were asked this question=431. Two trainees did not answer this question.

Exhibit reads: A total of 200 (47 percent) trainees reported that they experienced some difficulty balancing demands of IGERT versus their degree program.

Source: IGERT Trainee Survey, Item C9

Only a minority of trainees (17 percent) indicated that they had experienced a great deal of difficulty related to IGERT activities (Exhibit 4.11). Of those who reported any challenge, the two most frequently cited challenges were an increased workload due to IGERT participation (51 and 28 percent, respectively, rated this as "somewhat" or "a great deal" of a challenge) and difficulty balancing IGERT tasks with those of trainee's degree program (47 and 17 percent, respectively, rated this area as "somewhat" or "a great deal" of a challenge). Less than 10 percent of trainees indicated that they experienced a great deal of concern about their IGERT participation from students or faculty in their home discipline. Similarly, just a handful of trainees expressed a great deal of frustration trying to communicate with students from other disciplines.

Nearly 85 percent of those who responded to the close-ended question about challenges chose to respond to the open-ended question that asked them to describe the most challenging aspect of their IGERT training. The most common theme was the difficulty balancing IGERT with degree program requirements. For example, one trainee stated, "The most challenging aspect of participating in the IGERT program has been the additional time spent out of lab. There are more requirements for the IGERT than the normal degree requirements so I spend a significant amount of time in IGERT related meetings and courses which detracts from the amount of time spent in lab, however it is not so much time that I expect to have to push back my expected graduation."

Other common themes that emerged from the open-ended comments were an increased workload compared with non-IGERT trainees, challenges identifying or implementing an interdisciplinary research project, communication challenges (within interdisciplinary teams, communicating interdisciplinary research to the public) and difficulties associated with learning a new discipline.

Trainee Recommendations for the IGERT Program

Of the 37 percent of trainees who chose to write additional comments about their IGERT experience, most made project-specific recommendations that were unique to trainees' individual experiences.

Trainees suggested more support for new students considering interdisciplinary research, or for new IGERT trainees. The suggestions included ideas about providing information to students sooner about the specific requirements they, as trainees, would need to satisfy; about having had constructive suggestions from other students or faculty about how to succeed in interdisciplinary research environments –whether in readings, special course sessions, or other venues.

> **"Overall it was an excellent experience, though knowing the time requirements necessary for the IGERT requirements beforehand would have been very helpful in developing my Ph.D. program in a more timely manner."**
>
> ***- IGERT Trainee***

A handful of trainees emphasized the importance of external communication and outreach, including learning how to communicate effectively both within and outside of academia, which may turn out to be important for some trainees' future career paths. On a related note, some comments referenced the value of connections with the non-academic world, especially industry, whether through internships, mentoring relationships, or other avenues for helping students establish links with and potential transitions to industry. Less frequently, trainee open-ended comments acknowledged that industry internships are not necessarily appreciated by students' academic advisors, especially if an internship interferes with students' research-related responsibilities for their advisors' projects. As mentioned above, only 27 percent of survey respondents reported that they had participated in a non-academic internship.

> **"Communication with the general public is a weakness of science in general (not just IGERT). As a former journalist, this issue concerns me. Academia does not reward lay outreach and publications. Students should get credit for courses or activities enhancing communication such as writing or public speaking."**
>
> ***- IGERT Trainee***

Finally, some trainees mentioned specific challenges they faced with faculty, and offered some suggestions about how to deal with such challenges as well.

"…the shortfalls of my program were a result of the poor curriculum development and continuity of our specific faculty, not of the IGERT program in general. I would encourage IGERT to focus as much on the curriculum design and mentorship structure that PIs propose (for facilitating research preparedness) as on the specific research areas of study."

"… the advisors need training or material on how to do interdisciplinary research in order to advise the students, otherwise it is hard to detach ourselves from traditional research methods."

"I would recommend to students to … work with an Advisor that [sic] will support them in interdisciplinary research. From my experience, some professors have indicated that it is too complex to do interdisciplinary research in the early years of your academic career; that this should come later after the student has mastered one discipline."

"I hope that NSF can share results of this survey (and other info, studies) to the leaders of research universities to convey the importance of interdisciplinary research, so that this imperative trickles down to the professors. The majority of the professors I have worked with outside of IGERT are not interested in collaboration across disciplines, which has been disappointing."

Chapter 5: Summary of Findings

In presenting the study findings, this report has focused specifically on deepening understanding of those skills required to become an interdisciplinary research scientist; to do so, the study has used three complementary efforts. First, the study team reviewed the relevant research to learn what specific skills are identified as essential for conducting interdisciplinary scientific research. Next, the team drew from Abt's prior experience studying the IGERT Program to identify the mechanisms by which projects have historically trained their funded graduate students. Finally, the study team was guided by NSF and the study's external advisors. Insights from these efforts informed the development of the study's data collection and analysis activities.

Summary of Findings

There appears to be consensus about a set of competencies or skill sets that researchers have found characterize interdisciplinary research, including:

1. Depth of knowledge in one discipline or field of study
2. Ability to recognize the strengths and weaknesses of multiple disciplines
3. Ability to apply the approaches and tools from multiple disciplines to address a research problem
4. Ability to work in a team with individuals trained in different disciplines
5. Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines
6. Ability to communicate about interdisciplinary research to non-academic audiences (laypersons)

We used this set of skill areas as the point of departure to understand (1) how IGERT project PIs define interdisciplinarity, and (2) how trainees characterize the IGERT experiences explicitly designed to prepare them to become interdisciplinary researchers. The study team asked respondents, in more abstract terms, to rate the importance of these six skill areas, first, and then, more concretely, to describe the specific mechanisms or activities through which the projects hope to develop each of these skills (for PIs). Similarly, we asked trainees to rate the relative importance of these skills, the specific activities that trainees believe have been helpful for developing the skill areas, and how confident they are in the skills their IGERT experiences have helped to develop. Key findings related to the importance of specific skills reported by study respondents include:

- The six knowledge or skill areas were noted by both PIs and trainees as the primary skills they believe are important in conducting interdisciplinary research. Both PIs and trainees suggested that other skills are also important for conducting interdisciplinary research, including personality traits such as intellectual curiosity, and open-mindedness.
- Overall, the ratings provided by both PI and trainees are remarkably consistent across the six interdisciplinary competency ratings. Further, the overwhelming majority (85 percent or more) of both PIs and trainees characterized four of six competency areas as either important or very important.

- The two competency areas rated as important by the largest number of PIs and trainees included the ability to communicate research in one discipline to researchers trained in others (95 and 99 percent of PIs and trainees, respectively), and the capacity to work in a team setting with researchers from other disciplines (92 and 98 percent of PIs and trainees, respectively).
- An overwhelming majority of trainees (99 percent) and PIs (87 percent) indicated that the ability to understand both contributions and limitations of different disciplines, and the capacity to apply multidisciplinary approaches and tools in a research setting (86 and 96 percent of PIs and trainees, respectively) were essential in an interdisciplinary research setting.
- While rated as important by the majority of both PIs and trainees, slightly fewer respondents rated substantial depth of knowledge in one discipline and the ability to communicate interdisciplinary research to non-academic audiences as important for conducting interdisciplinary research (89 and 70 percent, and 73 and 85 percent, respectively, for PIs and trainees).
- PIs reported that they have quite specific qualities in mind when they select prospective IGERT trainees, including a strong academic background, interest and commitment to interdisciplinary research, prior research experience, and a flexible approach towards academic research.
- PIs reported that the most common ways of assessing trainees' capacity and progress toward becoming interdisciplinary scientists included relying on external evaluators and their faculty colleagues who supervise IGERT trainees. Other assessment methods involved monitoring the number and quality of trainee presentations, publications, job/post doc placements, research collaborations beyond IGERT, and monitoring trainee progress by using project-specific interdisciplinary competencies.

The study asked PIs and trainees to report more specifically on the mechanisms by which projects develop the skills required for interdisciplinary research. For PIs, that translated into which structured activities their projects offer, and for the trainees, that represented the graduate school learning experiences in which they had already participated. Key findings related to the activities provided, at the project level, and trainees' perceptions of how helpful the various activities were in developing their skills (and how confident they were about each of the six skill areas) include:

- PIs identified several different activities as the primary mechanisms by which trainees develop capacity to conduct interdisciplinary research: interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects. PIs reported that outreach activities represented the avenue through which they develop trainees' capacity to communicate research to laypersons.
- Trainees' reports were remarkably consistent with PI responses: over four-fifths of trainees reported that the same set of activities was helpful in developing their interdisciplinary research capacity across competency areas: courses and seminars in multiple disciplines, interdisciplinary courses, laboratory and field experiences, and interdisciplinary team research projects. The same pattern was evident in trainees' as PIs' responses about the use of outreach activities as the mechanism for learning to communicate research effectively to lay audiences: 90 percent of trainees rated outreach activities as the most helpful activity for that skill area in particular.
- The vast majority of trainees reported that they had participated in the following four IGERT activities: courses/seminars in multiple disciplines (97 percent), interdisciplinary courses (95 percent), hands-on laboratory and/or field experiences in disciplines related to the IGERT project (84 percent), and interdisciplinary team research projects (82 percent).

- Six of ten trainees indicated that their IGERT training helped them gain depth of knowledge in a single discipline.
- Trainees suggested that personality traits and transferable skills were also essential for conducting interdisciplinary research.
- The majority of trainees (from 71 to 94 percent) reported that they were confident in all six identified skills; over nine in ten trainees were confident in their ability to work in interdisciplinary teams and to communicate research in one discipline to researchers trained in other disciplines (94 and 90 percent, respectively).
- Examination of trainees' responses by such subgroups as gender and disciplinary affiliations revealed no significant differences. Not surprisingly, trainees who indicated they were closer to graduation had participated in a larger number of IGERT activities, and reported having more confidence in their abilities related to conducting interdisciplinary research.

Finally, the study asked about successes and challenges, at both the project and the individual trainee levels.

- The most common successes reported by PIs included increased visibility of interdisciplinary research among non-IGERT faculty and graduate students, and increased intellectual community among IGERT faculty and trainees.
- PIs attributed a number of accomplishments to IGERT, including fostering a community in which students collaborate to carry out meaningful research that engages not only IGERT but other students and faculty, which serves to increase the prominence of interdisciplinary research; using IGERT as a springboard for longer term institutional change; generating new research directions for faculty, and in one case, helping to establish an entire department within the host university.
- The PIs named difficulty balancing the demands of IGERT with those of the home degree program and the steep learning curve associated with learning new disciplines as common challenges for IGERT trainees. Another challenge was learning new disciplines well enough to engage effectively in interdisciplinary research projects, which seemed particularly challenging for some trainees in IGERT projects that incorporated engineering, advanced mathematics, or statistics, as not all students had the academic preparation for graduate level work in these disciplines.
- A minority of trainees reported having experienced difficulty related to IGERT; the two most frequently cited challenges were an increased workload due to IGERT participation (28 percent) and difficulty balancing IGERT and the degree program demands (17 percent).

Study Limitations

The current state of the research field on interdisciplinary research is such that there is no standard definition of interdisciplinarity, nor is there a conventional set of outcomes that can be used to assess the effectiveness or success of interdisciplinary training. Therefore, this study explored specific knowledge areas characterized as essential for developing interdisciplinary research capacity within the context of a sample of IGERT projects. The study describes how IGERT projects are designed, from the PI perspective, and how they are experienced, from the trainee perspective. An exploratory study can offer insights and directions for future research, although it cannot tell us whether exposure to, or participation in, certain activities *causes* individuals to become strong interdisciplinary scientists.

A second limitation is that the information collected reflects respondents' perceptions and reported experiences, and does not reflect direct measurement of PIs' and trainees' perceptions and experiences. Third, the study was limited to a purposively selected sample of active IGERT projects in institutional settings that, by definition, as IGERT grantees, are committed to interdisciplinary training. This sample was selected precisely to maximize the potential to answer the study's research questions, but as a result, its findings do not necessarily apply across all IGERT projects. However, based on demographic and institutional characteristics, the study sample and the census of IGERT projects are generally quite similar.

General Conclusions

The study findings suggest substantial congruence between the skills identified in the research literature and those identified by IGERT PIs as important for conducting interdisciplinary research. The findings also suggest that IGERT PIs and trainees alike perceive the same skill areas as essential, and further, that trainees characterize their IGERT experiences as helpful for developing these skills. Trainees credit their IGERT experiences with helping them become more confident in the multi-faceted set of skills needed in interdisciplinary research.

This descriptive study can inform collective understanding of how interdisciplinary research competencies are defined, operationalized and experienced in IGERT settings. The study findings may also provide some useful program knowledge for NSF about how PIs conceptualize interdisciplinary training, and how trainees experience IGERT activities as vehicles for becoming interdisciplinary researchers; it may also prove useful to others interested in understanding interdisciplinary training. Finally, by understanding the successes and challenges trainees face when participating in an interdisciplinary graduate training program, future IGERT PIs can potentially structure new projects to replicate successes and mitigate challenges.

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Appendix A: Back-up Exhibits for Chapters 2, 3, and 4

Chapter 2

Exhibit 1: Disciplines in which Trainees will receive their Doctoral Degrees

Discipline	N	%
Biological sciences	77	17.9
Chemical engineering	31	7.2
Other engineering	30	7.0
Chemistry, except biochemistry	20	4.6
Mechanical engineering	18	4.2
Other social sciences	17	3.9
Physics	16	3.7
Electrical/computer engineering	15	3.5
Environmental life sciences	13	3.0
Civil/architectural engineering	12	2.8
Economics	10	2.3
Computer and information sciences	9	2.1
Earth, atmospheric, and ocean sciences	9	2.1
Agricultural/food sciences	8	1.9
Political and related sciences	5	1.2
Sociology/anthropology	4	0.9
Biochemistry/biophysics and cell/molecular biology	3	0.7
Civil engineering and environmental engineering	3	0.7
Ecology and environmental science/studies	3	0.7
Ecology and microbiological sciences/immunology	3	0.7
Ecology and other biological sciences	3	0.7
Health	3	0.7
Industrial engineering	3	0.7
Mathematics and statistics	3	0.7
Plant sciences and genetics, animal/plant	3	0.7
Plant sciences and pharmacology, human/animal	3	0.7
Psychology	3	0.7
Biology, general and ecology	2	0.5
Cell/molecular biology and microbiological sciences/immunology	2	0.5
Chemistry, except biochemistry and materials engineering, including ceramics/textiles	2	0.5
Chemistry, except biochemistry and physics	2	0.5
Chemistry, except biochemistry and physics and materials engineering, including ceramics/textiles	2	0.5
Other biological sciences and anthropology/archaeology	2	0.5
Other biological sciences and bioengineering/biomedical engineering	2	0.5

Discipline	N	%
Other biological sciences and experimental psychology	2	0.5
Agricultural economics and economics	1	0.2
Agricultural engineering and bioengineering/biomedical engineering	1	0.2
Anthropology/archaeology and public health (including environmental health/epidemiology)	1	0.2
Applied mathematics and mathematics, general	1	0.2
Applied mathematics and other mathematics	1	0.2
Biochemistry/biophysics and chemistry, except biochemistry	1	0.2
Bioengineering/biomedical engineering and environmental engineering	1	0.2
Bioengineering/biomedical engineering and engineering sciences/mechanics/physics	1	0.2
Biology, general and computer science	1	0.2
Biology, general and anthropology/archaeology	1	0.2
Biology, general and computer science and bioengineering/biomedical engineering	1	0.2
Biology, general and computer/information sciences, general and health/medical technologies	1	0.2
Biology, general and microbiological sciences/immunology	1	0.2
Cell/molecular biology and chemical engineering and bioengineering/biomedical engineering	1	0.2
Cell/molecular biology and other computer/information sciences and bioengineering/biomedical engineering	1	0.2
Cell/molecular biology and pharmacology, human/animal	1	0.2
Civil engineering and other engineering	1	0.2
Computer programming and computer science and engineering, general	1	0.2
Computer science and computer/systems engineering	1	0.2
Computer science and economics	1	0.2
Computer science and experimental psychology	1	0.2
Computer science and mechanical engineering and other engineering	1	0.2
Computer/information sciences, general and computer science	1	0.2
Earth sciences and civil engineering and geophysical/geological engineering	1	0.2
Earth sciences and geological sciences, other	1	0.2
Earth sciences and other physical sciences	1	0.2
Ecology and computer science	1	0.2
Ecology and other computer/information sciences	1	0.2
Ecology and other physical sciences	1	0.2
Ecology and zoology, general	1	0.2
Ecology and anthropology/archaeology	1	0.2
Ecology and anthropology/archaeology and geography	1	0.2
Ecology and environmental science/studies and sociology and geography	1	0.2
Ecology and forestry sciences and economics	1	0.2
Economics and public policy studies	1	0.2

Discipline	N	%
Educational psychology and education, general	1	0.2
Electrical/electronics/communications engineering and materials engineering, including ceramics/textiles	1	0.2
Engineering sciences/mechanics/physics and materials engineering, including ceramics/textiles	1	0.2
Environmental science/studies and anthropology/archaeology	1	0.2
Environmental science/studies and applied mathematics and sociology	1	0.2
Environmental science/studies and chemistry, except biochemistry	1	0.2
Environmental science/studies and chemistry, except biochemistry and materials engineering, including ceramics/textiles	1	0.2
Environmental science/studies and chemistry, except biochemistry and civil engineering and environmental engineering	1	0.2
Environmental science/studies and earth sciences	1	0.2
Environmental science/studies and educational psychology and area/ethnic studies and education, general	1	0.2
Environmental science/studies and environmental engineering	1	0.2
Environmental science/studies and forestry sciences	1	0.2
Environmental science/studies and geography	1	0.2
Environmental science/studies and mechanical engineering	1	0.2
Environmental science/studies and other physical sciences and civil engineering and environmental engineering	1	0.2
Environmental science/studies and other physical sciences and sociology and other social sciences	1	0.2
Environmental science/studies and other social sciences	1	0.2
Experimental psychology and social psychology	1	0.2
Forestry sciences and bioengineering/biomedical engineering	1	0.2
Genetics, animal/plant and computer science	1	0.2
Geological sciences, other and oceanography	1	0.2
Geology and anthropology/archaeology	1	0.2
Geology and geological sciences, other	1	0.2
Mechanical engineering and materials engineering, including ceramics/textiles	1	0.2
Microbiological sciences/immunology and applied mathematics	1	0.2
Microbiological sciences/immunology and applied mathematics and chemical engineering	1	0.2
Microbiological sciences/immunology and bioengineering/biomedical engineering	1	0.2
Microbiological sciences/immunology and chemical engineering	1	0.2
Microbiological sciences/immunology and forestry sciences	1	0.2
Microbiological sciences/immunology and other biological sciences	1	0.2
Other agricultural sciences and ecology and political science/government	1	0.2
Other agricultural sciences and sociology and other social sciences	1	0.2
Other biological sciences and computer science and electrical/electronics/communications engineering and bioengineering/biomedical engineering	1	0.2
Other biological sciences and computer science and health/medical technologies	1	0.2

Discipline	N	%
Other biological sciences and economics	1	0.2
Other biological sciences and educational psychology and linguistics	1	0.2
Other biological sciences and environmental science/studies	1	0.2
Other biological sciences and other social sciences	1	0.2
Other biological sciences and political science/government	1	0.2
Other biological sciences and social psychology	1	0.2
Other computer/information sciences and computer/systems engineering	1	0.2
Other computer/information sciences and statistics	1	0.2
Other health/medical sciences and bioengineering/biomedical engineering	1	0.2
Other social sciences and other health/medical sciences	1	0.2
Physics and electrical/electronics/communications engineering	1	0.2
Physics and engineering sciences/mechanics/physics	1	0.2
Physics and materials engineering, including ceramics/textiles	1	0.2
Physics and other engineering	1	0.2
Plant sciences and biochemistry/biophysics	1	0.2
Plant sciences and chemical engineering	1	0.2
Political science/government and public policy studies	1	0.2
Public policy studies and other social sciences	1	0.2
Public policy studies and philosophy of science	1	0.2

Notes:
N=431 trainees. Missing=0 trainees.
Exhibit reads: A total of 77 (17.9 percent) trainees reported that they will receive their doctoral degree in Biological sciences
Source: IGERT Trainee Survey, Items A3.

Throughout the report, findings are generally presented for certain response options for a particular question. For example, in the report we present the percent of PIs who rated the study's competencies as "important" or "very important." The remaining tables present the actual percentages of responses in each category. The exhibits are labeled so that the reader can identify the corresponding location of the data in the main report.

Chapter 3

Exhibit 3.1: Importance of Specific Competencies in Conducting Interdisciplinary Research: PI Ratings

Interdisciplinary Competency	Not at all important	Somewhat Important	Important	Very Important	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N	N
Depth of knowledge in one discipline or field of study	2 (5)	2 (5)	8 (21)	26 (68)	1	39
Ability to recognize the strengths and weaknesses of multiple disciplines	2 (5)	3 (8)	11 (29)	22 (58)	1	39
Ability to apply the approaches and tools from multiple disciplines to address a research question	0 (0)	5 (14)	7 (19)	25 (68)	2	39
Ability to work in a team with individuals trained in different disciplines	1 (3)	2 (5)	11 (30)	23 (62)	2	39
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	0 (0)	2 (5)	7 (18)	30 (77)	0	39
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	2 (5)	8 (22)	12 (32)	15 (41)	2	39

Notes:

[a] Total refers to the number of IGERT PIs (n=39) who were asked these questions.

Number of responses to individual questions ranged from 37 to 39.

Exhibit reads: A total of 2 (5 percent) IGERT PIs (n=38) reported that "depth of knowledge in one discipline or field of study" was not at all important to conduct interdisciplinary research.

Source: PI Interview, Items 4A, 5A, 6A, 7A, 8A and 9A

Exhibit 3.2: Importance of Specific Competencies in Conducting Interdisciplinary Research: Trainee Ratings

	Not at all important	Somewhat Important	Important	Very Important	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N	N
Depth of knowledge in one discipline or field of study	10 (2)	119 (28)	173 (40)	129 (30)	0	431
Ability to recognize the strengths and weaknesses of multiple disciplines	1 (0)	4 (1)	115 (27)	311 (72)	0	431
Ability to apply the approaches and tools from multiple disciplines to address a research question	2 (0)	17 (4)	105 (24)	307 (71)	0	431
Ability to work in a team with individuals trained in different disciplines	2 (0)	6 (1)	57 (13)	366 (85)	0	431
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	1 (0)	3 (1)	53 (12)	374 (87)	0	431
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	7 (2)	57 (13)	121 (28)	246 (57)	0	431

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

No (0) trainees did not answer these questions.
Exhibit reads: A total of 10 (2 percent) trainees reported that "depth of knowledge in one discipline or field of study" was not at all important to conduct interdisciplinary research.

Source: IGERT Trainee Survey, Items B1,B2b, B3b, B4b, B5b and B6b

Exhibit 4.3: Overall Helpfulness of IGERT Training Activities in Developing Specific Interdisciplinary Competencies: Trainee Ratings

Interdisciplinary Competency	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N	N
Depth of knowledge in one discipline or field of study	39 (9)	131 (30)	167 (39)	94 (22)	0	431
Ability to recognize the strengths and weaknesses of multiple disciplines	7 (2)	54 (13)	178 (41)	192 (45)	0	431
Ability to apply the approaches and tools from multiple disciplines to address a research question	9 (2)	50 (12)	182 (42)	190 (44)	0	431
Ability to work in a team with individuals trained in different disciplines	8 (2)	45 (10)	134 (31)	244 (57)	0	431
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	9 (2)	41 (10)	175 (41)	206 (48)	0	431
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	30 (7)	96 (22)	152 (35)	153 (36)	0	431

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

No (0) trainees did not answer these questions.

Exhibit reads: A total of 39 (9 percent) trainees reported that their IGERT training was not at all helpful in developing their "depth of knowledge in one discipline or field of study."

Source: IGERT Trainee Survey, Items C2

Exhibit 4.4: Helpfulness of IGERT Training Activities in Developing the Ability to Recognize the Strengths and Weaknesses of Multiple Disciplines

IGERT Activity	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Don't Know	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N	N
Courses/seminars in multiple disciplines	3 (1)	24 (7)	153 (42)	175 (48)	6 (2)	1	362
Interdisciplinary courses/seminars	3 (1)	30 (8)	132 (37)	186 (52)	8 (2)	1	360
Journal clubs or research brown bags	4 (2)	40 (15)	122 (47)	89 (34)	7 (3)	1	263
Hands-on laboratory and/or field experiences	3 (1)	44 (14)	97 (31)	158 (51)	10 (3)	0	312
Internships in a non-academic setting	2 (2)	15 (15)	26 (25)	53 (52)	6 (6)	0	102
Interdisciplinary team research project	3 (1)	21 (7)	85 (28)	188 (61)	12 (4)	1	310
International research experiences	7 (5)	25 (19)	32 (24)	61 (47)	6 (5)	0	131
Mentorship from faculty	5 (2)	45 (15)	97 (33)	141 (48)	7 (2)	0	295
Outreach activities	56 (23)	75 (31)	54 (22)	50 (20)	9 (4)	0	244

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 3 (1 percent) trainees reported that courses/seminars in multiple disciplines were not at all helpful in developing their "ability to recognize the strengths and weaknesses of multiple disciplines."

Source: IGERT Trainee Survey, Item C4

Exhibit 4.5: Helpfulness of IGERT Training Activities in Developing the Ability to Apply the Approaches and Tools from Multiple Disciplines: Trainee Ratings

IGERT Activity	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Don't Know	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N	N
Courses/seminars in multiple disciplines	2 (1)	54 (15)	146 (40)	160 (44)	2 (1)	0	364
Interdisciplinary courses/seminars	1 (0)	48 (13)	139 (39)	169 (47)	3 (1)	0	360
Journal clubs or research brown bags	11 (4)	80 (30)	100 (37)	70 (26)	8 (3)	0	269
Hands-on laboratory and/or field experiences	2 (1)	33 (10)	100 (32)	173 (55)	9 (3)	0	317
Internships in a non-academic setting	6 (6)	17 (16)	29 (28)	45 (43)	7 (7)	0	104
Interdisciplinary team research project	4 (1)	33 (10)	85 (27)	183 (58)	11 (3)	0	316
International research experiences	3 (2)	25 (19)	31 (24)	62 (48)	9 (7)	0	130
Mentorship from faculty	6 (2)	52 (18)	94 (32)	136 (46)	6 (2)	0	294
Outreach activities	76 (31)	79 (33)	43 (18)	37 (15)	7 (3)	0	242

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 2 (1 percent) trainees reported that courses/seminars in multiple disciplines were not at all helpful in developing their "ability to apply the approaches and tools from multiple disciplines."

Source: IGERT Trainee Survey, Item C5

Exhibit 4.6: Helpfulness of IGERT Training Activities in Developing the Ability to Work in an Interdisciplinary Team: Trainee Ratings

IGERT Activity	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Don't Know	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N	N
Courses/seminars in multiple disciplines	16 (4)	89 (24)	118(32)	142 (38)	5 (1)	0	370
Interdisciplinary courses/seminars	12 (3)	56 (15)	133(36)	161 (44)	3 (1)	0	365
Journal clubs or research brown bags	23 (9)	77 (29)	93(35)	67 (25)	9 (3)	0	269
Hands-on laboratory and/or field experiences	3 (1)	40 (12)	83(26)	188 (59)	7 (2)	0	321
Internships in a non-academic setting	4 (4)	10 (9)	29(26)	59 (54)	8 (7)	0	110
Interdisciplinary team research project	0 (0)	12 (4)	57(18)	239 (75)	12 (4)	0	320
International research experiences	1 (1)	16 (12)	40(29)	71 (52)	9 (7)	0	137
Mentorship from faculty	9 (3)	49 (17)	115(39)	119 (40)	4 (1)	0	296
Outreach activities	36(14)	88 (35)	69(28)	44 (18)	12 (5)	0	249

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 16 (4 percent) trainees reported that courses/seminars in multiple disciplines were not at all helpful in developing their "ability to work in an interdisciplinary team."

Source: IGERT Trainee Survey, Item C6

Exhibit 4.7: Helpfulness of IGERT Training Activities in Developing the Ability to Communicate to Researchers from Different Disciplines: Trainee Ratings

IGERT Activity	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Don't Know	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N	N
Courses/seminars in multiple disciplines	7 (2)	60 (16)	148 (40)	153 (41)	5 (1)	0	373
Interdisciplinary courses/seminars	3 (1)	48 (13)	156 (43)	157 (43)	3 (1)	0	367
Journal clubs or research brown bags	9 (3)	49 (18)	91 (33)	119 (43)	7 (3)	0	275
Hands-on laboratory and/or field experiences	13 (4)	72 (22)	119 (36)	119 (36)	9 (3)	0	332
Internships in a non-academic setting	2 (2)	15 (14)	36 (33)	49 (45)	6 (6)	0	108
Interdisciplinary team research project	2 (2)	22 (7)	95 (30)	191 (60)	12 (4)	0	322
International research experiences	5 (4)	17 (12)	39 (28)	69 (50)	7 (5)	0	137
Mentorship from faculty	13 (4)	63 (21)	107 (36)	110 (37)	5 (2)	0	298
Outreach activities	34 (13)	69 (27)	68 (26)	76 (30)	10 (4)	0	257

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 7 (2 percent) trainees reported that courses/seminars in multiple disciplines were not at all helpful in developing their "ability to communicate to researchers from different disciplines."

Source: IGERT Trainee Survey, Item C7

Exhibit 4.8: Helpfulness of IGERT Training Activities in Developing the Ability to Communicate about Interdisciplinary Research to Laypersons: Trainee Ratings

IGERT Activity	Not at all helpful	Somewhat helpful	Helpful	Very helpful	Don't Know	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N (%)	N	N
Courses/seminars in multiple disciplines	31 (10)	99 (33)	99 (33)	69(23)	2 (1)	0	300
Interdisciplinary courses/seminars	32 (11)	78 (27)	108 (37)	72(25)	3 (1)	0	293
Journal clubs or research brown bags	27 (12)	59 (26)	79 (35)	54(24)	5 (2)	0	224
Hands-on laboratory and/or field experiences	33 (13)	75 (29)	78 (30)	68(26)	6 (2)	0	260
Internships in a non-academic setting	7 (8)	9 (10)	30 (33)	41(45)	5 (5)	0	92
Interdisciplinary team research project	17 (7)	60 (23)	93 (36)	79(30)	11 (4)	0	260
International research experiences	6 (6)	12 (11)	42 (39)	44(40)	5 (5)	0	109
Mentorship from faculty	32 (13)	79 (33)	85 (35)	42(17)	5 (2)	0	243
Outreach activities	4 (2)	12 (6)	46 (21)	147(68)	7 (3)	0	216

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 31 (10 percent) trainees reported that courses/seminars in multiple disciplines were not at all helpful in developing their "ability to communicate about interdisciplinary research to laypersons."

Source: IGERT Trainee Survey, Item C8

Exhibit 4.9: Challenges Faced as a result of IGERT: Trainee Ratings

IGERT Activity	Not at all	Somewhat	A great deal	Missing	Total[a]
	N (%)	N (%)	N (%)	N	N
Difficulty balancing demands of IGERT versus my degree program	156 (36)	200 (47)	73 (17)	2	431
An increased workload compared with peers who are not IGERT trainees	92 (21)	217 (51)	120 (28)	2	431
Concern about my participation in IGERT from students or faculty in my primary discipline	300 (70)	89 (21)	40 (9)	2	431
Frustration trying to communicate with students from other primary disciplines	305 (71)	100 (23)	24 (6)	2	431

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 156 (36 percent) trainees reported that they experienced no difficulty in balancing demands of IGERT versus their degree program.

Source: IGERT Trainee Survey, Item C9

Exhibit 4.10: Trainees' Level of Confidence in Interdisciplinary Competencies

Interdisciplinary Competency	Not at all confident	Somewhat confident	Confident	Very confident	Missing	Total[a]
	N (%)	N (%)	N (%)	N (%)	N	N
Depth of knowledge in one discipline or field of study	7 (2)	70 (16)	221 (51)	133 (31)	0	431
Ability to recognize the strengths and weaknesses of multiple disciplines	5 (1)	90 (21)	224 (52)	111 (26)	1	431
Ability to apply the approaches and tools from multiple disciplines to address a research question	7 (2)	117 (27)	197 (46)	109 (25)	1	431
Ability to work in a team with individuals trained in different disciplines	1 (0)	25 (6)	149 (35)	255 (59)	1	431
Ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines	1 (0)	45 (10)	213 (50)	170 (40)	2	431
Ability to communicate about interdisciplinary research to nonacademic audiences (laypersons)	4 (1)	79 (18)	181 (42)	167 (39)	0	431

Notes:

[a] Total refers to the number of IGERT trainees who were asked these questions.

Exhibit reads: A total of 7 (2 percent) trainees reported that they were not at all confident in their "depth of knowledge in one discipline or field of study."

Source: IGERT Trainee Survey, Items B8.

Appendix B: IGERT PI Interview Protocol

Introduction

This is [**name**], from Abt Associates. How are you? Abt Associates is working with the National Science Foundation to conduct a study about how the IGERT projects prepare students to work as interdisciplinary researchers. One major component of this study is interviews with Principal Investigators from the 2007 and 2008 cohorts of IGERT projects.

I want to start off by thanking you for agreeing to participate in this interview.

- Before we begin this interview, I want to remind you that your participation is voluntary and you may choose to stop this interview at any point.
- Your responses to our questions will be aggregated with those of other PIs and we will not attribute particular comments or suggestions to specific individuals. Your participation in this interview is voluntary, so if you prefer not to answer a question, or if you want to end this interview for any reason – just let me know.

Burden Disclosure Statement

According to the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number. The valid OMB control number for this collection is 3145-0219; this number is valid through 03/31/2015. Public reporting burden for this collection of information is estimated to average 75 minutes.

[If using a note taker]

Also, my colleague, [**name2**], is on the telephone with me; she will help me take notes during the interview.

[If using a tape recorder]

I'd like to audiotape our conversation so that I can listen at a later time for points I might miss during the conversation. Is that okay with you?

Instructions

I'd like to proceed with the interview questions. Please let me know at any point during the interview if you would like me to repeat a phrase or question or provide clarification on any terms or phrases that you do not understand.

Do you have any questions before we begin?

Protocol

1. Have you been the PI of this IGERT project since it was initially awarded? When did you become the PI?

2. Did you help to develop the proposal for this IGERT?

   IF YES:

   - How did you get involved in working on the proposal?
   - What was your motivation for bringing an IGERT project to UNIVERSITY?
   - How did faculty from departments other than your own become involved in conceptualizing a plan for IGERT?

   IF NO:

   - When did you become involved in the IGERT project?

   2-1. How do you define interdisciplinarity?

3. With regard to recruiting or selecting students for IGERT, what do you look for in students?
   - Are there specific characteristics, interests, and/or skills that you prefer students to have?

Next, I'd like to ask you about different types of knowledge and abilities that may or may not be important to facilitate interdisciplinary research.

[If need explanation of what we mean by training activities – use examples from this list]

- *Discipline specific courses/seminars across multiple disciplines*
- *Courses/seminars that specifically cover interdisciplinary topics related to your IGERT theme*
- *Hands-on laboratory and/or field experiences in disciplines related to your IGERT project*
- *Journal clubs or research brown bags*
- *Internships in a non-academic setting (industry, business, government, etc.)*
- *Interdisciplinary team research project*
- *International research experiences*
- *Mentorship from faculty in disciplines other than students' primary discipline*

Any questions before I proceed?

4. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to have depth of knowledge in one discipline or field of study? *Not at all important, somewhat important, important, very important*

   B) How does your IGERT project develop trainees' depth of knowledge in one discipline or field of study?

   Are there [any other] training activities that are part of your IGERT project that specifically contribute to developing this depth of knowledge in a single discipline?

By "training activities" I mean things like seminars or journal clubs, internships, team research projects, lab rotations – anything your IGERT project uses to develop students' depth of knowledge in a primary discipline.

5. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to recognize the strengths and weaknesses of multiple disciplines? *Not at all important, somewhat important, important, very important*

   B) How does your IGERT project develop trainees' ability to recognize the strengths and weaknesses of multiple disciplines?

   Are there [any other] training activities that are part of your IGERT project that specifically contribute to developing this ability?

6. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to apply the approaches and tools from multiple disciplines to address a research problem? *Not at all important, somewhat important, important, very important*

   B) How does your IGERT project develop trainees' ability to apply the approaches and tools of multiple disciplines to address a research problem?

   Are there [any other] training activities that are part of your IGERT project that specifically contribute to developing this ability?

7. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to work in a team with individuals trained in different disciplines? *Not at all important, somewhat important, important, very important*

   B) How does your IGERT project develop trainees' ability to work in a team with individuals trained in different disciplines?

   Are there [any other] training activities that are part of your IGERT project that specifically contribute to developing this ability?

8. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to communicate (orally and in writing) about research based in one discipline to researchers trained in different disciplines? *Not at all important, somewhat important, important, very important*

   B) How does your IGERT project develop students' ability to communicate about research based in one discipline to researchers trained in different disciplines?

   Are there [any other] training activities that are part of your IGERT project that specifically contribute to trainees' ability to communicate with academic audiences from other disciplines?

9. A) To conduct interdisciplinary research, how important is it for trainees in your IGERT project to communicate (orally and in writing) about interdisciplinary research to non-academic audiences (laypersons)? *Not at all important, somewhat important, important, very important*

B) How does your IGERT project develop students' ability to communicate about interdisciplinary research to non-academic audiences?

Are there [any other] training activities that are part of your IGERT project that specifically contribute to trainees' ability to communicate to non-academic audiences?

10. What other skills, abilities, or types of knowledge do you find are important to facilitate conducting interdisciplinary research?
    - Probe:
        - *Why is this skill area important for interdisciplinary research*
        - *How does your IGERT project help to develop that [skill/ability/knowledge]?*

11. How does your IGERT project assess or monitor students' development as an interdisciplinary researcher?
    - Do you use any specific measures or tests to assess students' interdisciplinary research capacity?
    - What are key indicators that students understand how to conduct interdisciplinary research?

12. What challenges or difficulties have you observed IGERT students experiencing with the program?

13. Which elements of your IGERT project do you think are working well? Which elements would you like to see improved?

Closing

14. Would you like to add anything else about your IGERT project?

Thank you very much for your time today. The input you've provided will be used to improve and refine the interview protocol as it stands.

Appendix C: IGERT Trainee Survey

SECTION A: YOUR CURRENT DEGREE PROGRAM

The first few questions are about your current status in your degree program.

A1 As of <insert reference date>, have you graduated from your doctoral degree program? *Check one response*

☐ 1 Yes
☐ 2 No

[Programming note: If A1=1, skip to question A4]

A2 [Programming note: There is no question A2]

A3 Please select the discipline(s) in which you will receive your doctoral degree.

First, indicate which of the four broader areas in which your discipline(s) falls. If your doctoral degree is best characterized as interdisciplinary, please select up to two broad areas, if applicable.

[Source: Adapted from the 2006 Survey of Doctoral Recipients]

Check up to two responses

☐ 1 Sciences (e.g., Agricultural/food sciences; Biological sciences; Environmental life sciences; Computer and information sciences; Mathematics and statistics; Chemistry; Earth, atmospheric and ocean sciences; Physics; Psychology)

☐ 2 Social Sciences (e.g., Economics; Political and related sciences; Sociology/Anthropology; Other Social Sciences)

☐ 3 Health/Medical Fields

☐ 4 Engineering

[Programming note: If R selects one area from above, display one of four screens based on choice above
1. Sciences screen
2. Social Sciences screen
3. Health/Medical Fields screen
4. Engineering screen

The next four pages should each be on a separate screen.
If R selects two broad areas; display two of the four screens based on choices above.]

Science Fields

To view other fields (Social Sciences, Health/Medical, Engineering), please select Go back to the 4 broad areas to change your selection.

[Programming note: The blue underlined text above will function just like the "Go back to the 4 broad areas" button at the bottom of the page.]

Agricultural/food sciences	❍ Animal sciences ❍ Food sciences/technology	❍ Plant sciences ❍ OTHER agricultural sciences
Biological sciences *Bioengineering, see ENGINEERING, next page*	❍ Biochemistry/biophysics ❍ Biology, general ❍ Botany ❍ Cell/molecular biology ❍ Ecology ❍ Genetics, animal/plant	❍ Microbiological sciences/immunology ❍ Nutritional sciences ❍ Pharmacology, human/animal ❍ Physiology and pathology, human/animal ❍ Zoology, general ❍ OTHER Biological sciences
Environmental life sciences	❍ Environmental science/studies	❍ Forestry sciences
Computer and information sciences *For Computer Engineering, see ENGINEERING, next page*	❍ Computer/information sciences, general ❍ Computer programming ❍ Computer science	❍ Computer systems analysis ❍ Information services/systems ❍ OTHER computer/information sciences
Mathematics and statistics	❍ Applied mathematics ❍ Mathematics, general ❍ Operations research	❍ Statistics ❍ OTHER mathematics
Chemistry, except biochemistry	❍ Chemistry except biochemistry (*biochemistry, see Biological sciences*)	
Earth, atmospheric, and ocean sciences	❍ Atmospheric sciences/meteorology ❍ Earth sciences ❍ Geology	❍ Geological sciences, other ❍ Oceanography ❍ OTHER physical sciences
Physics *Biophysics, see Biological Sciences*	❍ Astronomy/astrophysics	❍ Physics
Psychology	❍ Clinical psychology ❍ Counseling ❍ Educational psychology ❍ Experimental psychology	❍ General psychology ❍ Industrial/organizational psychology ❍ Social psychology ❍ OTHER psychology

NEXT ITEM

GO BACK TO THE 4 BROAD AREAS

Social Sciences

To view other fields (Sciences, Engineering, Health/Medical), please select Go back to the 4 broad areas to change your selection.

[Programming note: The blue underlined text above will function just like the "Go back to the 4 broad areas" button at the bottom of the page.]

Economics	❍ Agricultural economics	❍ Economics
Political and related sciences	❍ International relations ❍ Political science/government	❍ Public policy studies
Sociology/Anthropology	❍ Anthropology/archaeology ❍ Criminology	❍ Sociology
OTHER social sciences	❍ Area/ethnic studies ❍ Education, general ❍ Geography ❍ History of science	❍ Linguistics ❍ Philosophy of science ❍ OTHER social sciences

NEXT ITEM
GO BACK TO THE 4 BROAD AREAS

Health/Medical fields

To view other fields (Sciences, Engineering, Social Sciences), please select Go back to the 4 broad areas to change your selection.

[Programming note: The blue underlined text above will function just like the "Go back to the 4 broad areas" button at the bottom of the page.]

Health	❍ Audiology/speech pathology ❍ Health services administration ❍ Health/medical assistants ❍ Health/medical technologies ❍ Medical preparatory programs (e.g., pre-dentistry, pre-medical, pre- veterinary) ❍ Medicine (e.g., general, internal, orthopedic, surgical, dentistry, optometry, osteopathic, podiatry, veterinary)	❍ Nursing (4 years or longer program) ❍ Pharmacy ❍ Physical therapy and other rehabilitation/therapeutic services ❍ Public health (Including environmental health/epidemiology) ❍ OTHER health/medical sciences

NEXT ITEM
GO BACK TO THE 4 BROAD AREAS

Engineering Fields

To view other fields (Sciences, Social Science, Health/Medical), please select Go back to the 4 broad areas to change your selection.

[Programming note: The blue underlined text above will function just like the "Go back to the 4 broad areas" button at the bottom of the page.]

Biochemical engineering, *see Bioengineering/biomedical under OTHER Engineering*		
Chemical engineering	❍ Chemical engineering	
Civil/architectural eng.	❍ Architectural engineering	❍ Civil engineering
Electrical/computer engineering	❍ Computer/systems engineering	❍ Electrical/electronics/communications engineering
Industrial engineering	❍ Industrial/manufacturing engineering	
Mechanical engineering	❍ Mechanical engineering	
OTHER engineering	❍ Aerospace/aeronautical/ astronautical engineering ❍ Agricultural engineering ❍ Bioengineering/biomedical engineering ❍ Engineering, general ❍ Engineering sciences/ mechanics/physics ❍ Environmental engineering	❍ Geophysical/geological engineering ❍ Materials engineering, including ceramics/textiles ❍ Metallurgical engineering ❍ Mining/minerals engineering ❍ Naval architecture/marine engineering ❍ Nuclear engineering ❍ Petroleum engineering ❍ OTHER engineering

NEXT ITEM
GO BACK TO THE 4 BROAD AREAS

SECTION B: CONDUCTING INTERDISCIPLINARY RESEARCH

The next set of questions asks about conducting interdisciplinary research as characterized by certain types of knowledge, skills and abilities and how important each one is to conducting research.

B1 To conduct interdisciplinary research, how important is it for someone to have *depth of knowledge in one discipline or field of study*?

Not at all important	Somewhat important	Important	Very important
☐0	☐1	☐2	☐3

B2 How important is it for someone to have the *ability to recognize the strengths and weaknesses of multiple disciplines* to conduct…

	The ability to recognize the strengths and weaknesses of multiple disciplines			
	Not at all important	Somewhat important	Important	Very important
a. Research in a single discipline or field of study	☐0	☐1	☐2	☐3
b. Interdisciplinary research	☐0	☐1	☐2	☐3

B3 How important is it for someone to have the *ability to apply the approaches and tools from multiple disciplines to address a research question* to conduct…

	The ability to apply the approaches and tools from multiple disciplines to address a research question			
	Not at all important	Somewhat important	Important	Very important
a. Research in a single discipline or field of study	☐0	☐1	☐2	☐3
b. Interdisciplinary research	☐0	☐1	☐2	☐3

B4 How important is it for someone to have the *ability to work in a team with individuals trained in different disciplines* to conduct…

	The ability to work in a team with individuals trained in different disciplines			
	Not at all important	**Somewhat important**	**Important**	**Very important**
a. Research in a single discipline or field of study	☐0	☐1	☐2	☐3
b. Interdisciplinary research	☐0	☐1	☐2	☐3

B5 How important is it for someone to have the *ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines* to conduct…

	The ability to communicate research based in one discipline or field of study to academic researchers trained in different disciplines			
	Not at all important	**Somewhat important**	**Important**	**Very important**
a. Research in a single discipline or field of study	☐0	☐1	☐2	☐3
b. Interdisciplinary research	☐0	☐1	☐2	☐3

B6 How important is it for someone to have the *ability to communicate about interdisciplinary research to non-academic audiences (laypersons)* to conduct…

	The ability to communicate about interdisciplinary research to non-academic audiences (laypersons)			
	Not at all important	**Somewhat important**	**Important**	**Very important**
a. Research in a single discipline or field of study	☐0	☐1	☐2	☐3
b. Interdisciplinary research	☐0	☐1	☐2	☐3

B7 In addition to the types of knowledge, skills and abilities that you have identified as important in the previous questions, what other knowledge, skills, or abilities are important for conducting interdisciplinary research?

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

B8 As of <insert reference date>, how confident are you about your knowledge, skills or abilities in the following areas? *Check one response per row*

		Not at all confident	Somewhat confident	Confident	Very Confident
a.	Depth of knowledge in one discipline or field of study	☐0	☐1	☐2	☐3
b.	Ability to recognize the strengths and weaknesses of multiple disciplines	☐0	☐1	☐2	☐3
c.	Ability to apply the approaches and tools from multiple disciplines to address a research question	☐0	☐1	☐2	☐3
d.	Ability to work in a team with individuals trained in different disciplines	☐0	☐1	☐2	☐3
e.	Ability to communicate research based in one discipline or field of study to **academic researchers trained in different disciplines**	☐0	☐1	☐2	☐3
f.	Ability to communicate about interdisciplinary research to **non-academic audiences (laypersons)**	☐0	☐1	☐2	☐3

SECTION C: YOUR IGERT TRAINING

The next set of questions focuses on your IGERT training and whether it has helped you to develop and/or enhance your knowledge, skills or abilities in different areas as well as your overall capacity to conduct interdisciplinary research.

C1 Have you participated in any of the following IGERT training activities? *Check one response per row*

IGERT activities	Yes	No
a. Courses/seminars in multiple disciplines	☐1	☐2
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐1	☐2
c. Journal clubs or research brown bags	☐1	☐2
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐1	☐2
e. Internships in a non-academic setting (industry, business, government, etc.)	☐1	☐2
f. Interdisciplinary team research project	☐1	☐2
g. International research experiences	☐1	☐2
h. Mentorship from faculty from outside your home department	☐1	☐2
i. Outreach activities (K-12 students, the general public etc.)	☐1	☐2

C2 Overall, how helpful has your IGERT training been in developing the following knowledge, skills or abilities? *Check one response per row*

	Not at all helpful	Somewhat helpful	Helpful	Very helpful
a. Depth of knowledge in one discipline or field of study	☐0	☐1	☐2	☐3
b. Ability to recognize the strengths and weaknesses of multiple disciplines	☐0	☐1	☐2	☐3
c. Ability to apply the approaches and tools from multiple disciplines to address a research question	☐0	☐1	☐2	☐3
d. Ability to work in a team with individuals trained in different disciplines	☐0	☐1	☐2	☐3
e. Ability to communicate research based in one discipline or field of study to **academic researchers trained in different disciplines**	☐0	☐1	☐2	☐3
f. Ability to communicate about interdisciplinary research to **non-academic audiences (laypersons)**	☐0	☐1	☐2	☐3

C3 What other knowledge, skills or abilities has your IGERT training helped you develop?
If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

[Programming note: The next set of questions will be driven by how students respond to C2 – if students indicate that their overall IGERT training has been "helpful" or "very helpful" in developing them in the areas (C2b through C2f), they will receive a follow up question asking them to indicate how helpful specific IGERT activities have been in developing that respective area. For example, if the respondent indicates that their IGERT training was very helpful in developing their ability to recognize the strengths and weaknesses of multiple disciplines, they will receive a follow up question. Note: A follow-up question will not appear for C2a].

[Programming note: C4 will only appear if C2b=2 or 3. Present items where C1=1]

C4 Reflecting on your IGERT experience so far, how helpful have the following IGERT training activities been in terms of developing your *ability to recognize the strengths and weaknesses of multiple disciplines*? *Check one response per row*

IGERT activities [Items will only appear if C1=1]	**Not at all helpful**	**Somewhat helpful**	**Helpful**	**Very helpful**	**Do not know**
a. Courses/seminars in multiple disciplines	☐0	☐1	☐2	☐3	☐99
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐0	☐1	☐2	☐3	☐99
c. Journal clubs or research brown bags	☐0	☐1	☐2	☐3	☐99
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐0	☐1	☐2	☐3	☐99
e. Internships in a non-academic setting (industry, business, government, etc.)	☐0	☐1	☐2	☐3	☐99
f. Interdisciplinary team research project	☐0	☐1	☐2	☐3	☐99
g. International research experiences	☐0	☐1	☐2	☐3	☐99
h. Mentorship from faculty from outside your home department	☐0	☐1	☐2	☐3	☐99
i. Outreach activities (K-12 students, the general public etc.)	☐0	☐1	☐2	☐3	☐99

C4a. Are there other IGERT training activities that have been helpful or very helpful in developing *your ability to recognize the strengths and weaknesses of multiple disciplines*? If so, please describe.

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

[Programming note: C5 will only appear if C2c=2 or 3. Present items where C1=1]

C5 Reflecting on your IGERT experience so far, how helpful have the following IGERT training activities been in terms of developing your *ability to apply the approaches and tools from multiple disciplines to address a research question*? *Check one response per row*

IGERT activities [Items will only appear if C1=1]	**Not at all helpful**	**Somewhat helpful**	**Helpful**	**Very helpful**	**Do not know**
a. Courses/seminars in multiple disciplines	☐0	☐1	☐2	☐3	☐99
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐0	☐1	☐2	☐3	☐99
c. Journal clubs or research brown bags	☐0	☐1	☐2	☐3	☐99
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐0	☐1	☐2	☐3	☐99
e. Internships in a non-academic setting (industry, business, government, etc.)	☐0	☐1	☐2	☐3	☐99
f. Interdisciplinary team research project	☐0	☐1	☐2	☐3	☐99
g. International research experiences	☐0	☐1	☐2	☐3	☐99
h. Mentorship from faculty from outside your home department	☐0	☐1	☐2	☐3	☐99
i. Outreach activities (K-12 students, the general public etc.)	☐0	☐1	☐2	☐3	☐99

C5a. Are there other IGERT training activities that have been helpful or very helpful in developing your *ability to apply the approaches and tools from multiple disciplines to address a research question?* If so, please describe.

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

[Programming note: C6 will only appear if C2d=2 or 3. Present items where C1=1]

C6 Reflecting on your IGERT experience so far, how helpful have the following IGERT training activities been in terms of developing your *ability to work in a team with individuals trained in different disciplines*? *Check one response per row*

IGERT activities [Items will only appear if C1=1]	**Not at all helpful**	**Somewhat helpful**	**Helpful**	**Very helpful**	**Do not know**
a. Courses/seminars in multiple disciplines	☐0	☐1	☐2	☐3	☐99
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐0	☐1	☐2	☐3	☐99
c. Journal clubs or research brown bags	☐0	☐1	☐2	☐3	☐99
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐0	☐1	☐2	☐3	☐99
e. Internships in a non-academic setting (industry, business, government, etc.)	☐0	☐1	☐2	☐3	☐99
f. Interdisciplinary team research project	☐0	☐1	☐2	☐3	☐99
g. International research experiences	☐0	☐1	☐2	☐3	☐99
h. Mentorship from faculty from outside your home department	☐0	☐1	☐2	☐3	☐99
i. Outreach activities (K-12 students, the general public etc.)	☐0	☐1	☐2	☐3	☐99

C6a. Are there other IGERT training activities that have been helpful or very helpful in developing your *ability to work in a team with individuals trained in different disciplines?* If so, please describe.

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

[Programming note: C7 will only appear if C2e=2 or 3. Present items where C1=1]

C7 Reflecting on your IGERT experience so far, how helpful have the following IGERT training activities been in terms of developing your *ability to communicate research based in one discipline or field of study to* ***academic researchers trained in different disciplines***? *Check one response per row*

IGERT activities [Items will only appear if C1=1]	**Not at all helpful**	**Somewhat helpful**	**Helpful**	**Very helpful**	**Do not know**
a. Courses/seminars in multiple disciplines	☐0	☐1	☐2	☐3	☐99
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐0	☐1	☐2	☐3	☐99
c. Journal clubs or research brown bags	☐0	☐1	☐2	☐3	☐99
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐0	☐1	☐2	☐3	☐99
e. Internships in a non-academic setting (industry, business, government, etc.)	☐0	☐1	☐2	☐3	☐99
f. Interdisciplinary team research project	☐0	☐1	☐2	☐3	☐99
g. International research experiences	☐0	☐1	☐2	☐3	☐99
h. Mentorship from faculty from outside your home department	☐0	☐1	☐2	☐3	☐99
i. Outreach activities (K-12 students, the general public etc.)	☐0	☐1	☐2	☐3	☐99

C7a. Are there other IGERT training activities that have been helpful or very helpful in developing your *ability to communicate research based in one discipline or field of study to* ***academic researchers trained in different disciplines***? If so, please describe.

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

[Programming note: C8 will only appear if C2f=2 or 3. Present items where C1=1]

C8 Reflecting on your IGERT experience so far, how helpful have the following IGERT training activities been in terms of developing your *ability to communicate about interdisciplinary research to* ***non-academic audiences (laypersons)***? *Check one response per row*

IGERT activities [Items will only appear if C1=1]	**Not at all helpful**	**Somewhat helpful**	**Helpful**	**Very helpful**	**Do not know**
a. Courses/seminars in multiple disciplines	☐0	☐1	☐2	☐3	☐99
b. Interdisciplinary courses/seminars that covered topics related to your IGERT theme	☐0	☐1	☐2	☐3	☐99
c. Journal clubs or research brown bags	☐0	☐1	☐2	☐3	☐99
d. Hands-on laboratory and/or field experiences in disciplines related to your IGERT project	☐0	☐1	☐2	☐3	☐99
e. Internships in a non-academic setting (industry, business, government, etc.)	☐0	☐1	☐2	☐3	☐99
f. Interdisciplinary team research project	☐0	☐1	☐2	☐3	☐99
g. International research experiences	☐0	☐1	☐2	☐3	☐99
h. Mentorship from faculty from outside your home department	☐0	☐1	☐2	☐3	☐99
i. Outreach activities (K-12 students, the general public etc.)	☐0	☐1	☐2	☐3	☐99

C8a. Are there other IGERT training activities that have been helpful or very helpful in developing your *ability to communicate about interdisciplinary research to* ***non-academic audiences (laypersons)***? If so, please describe.

If none, please check here: ❑ NONE

[Textbox, 1,000 characters]

C9 Have you experienced any of the following as a result of your IGERT training? *Check one response per row.*

	Not at all	Somewhat	A great deal
a. Difficulty balancing demands of IGERT versus my degree program	☐1	☐2	☐3
b. An increased work load than peers who are not IGERT trainees	☐1	☐2	☐3
c. Concern about my participation in IGERT from students or faculty in my primary discipline	☐1	☐2	☐3
d. Frustration trying to communicate with students from other primary disciplines	☐1	☐2	☐3

C10 What has been the most difficult or challenging aspect of participating in your IGERT training program?

[Textbox, 1,000 characters]

SECTION D: DEMOGRAPHIC INFORMATION

D1 Are you……
[Source: Adapted from the 2006 Survey of Doctoral Recipients]

☐ 1 Male
☐ 2 Female

D2 Are you Hispanic or Latino?
[Source: Adapted from the 2006 Survey of Doctoral Recipients]

☐ 1 Yes
☐ 2 No

D3 What is your racial background? [Source: Adapted from the 2006 Survey of Doctoral Recipients]
Check one or more.

☐ 1 American Indian or Alaska Native
☐ 2 Native Hawaiian or other Pacific Islander
☐ 3 Asian
☐ 4 Black or African-American
☐ 5 White

SECTION E: RECOMMENDATIONS

E1 If you have any other comments—about this study, your IGERT experience, or suggestions to increase students' preparedness for interdisciplinary research—please note them below.

[Textbox, 1,000 characters]

On behalf of the National Science Foundation and the IGERT program, thank you for taking the time to complete this survey!

Click here to submit your responses: **SUBMIT**