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The Snowbird Charrette: An Experimental Study of Interdisciplinary Collaboration in the Design of Environmental Research

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"It is much easier to find one's way if one isn't too familiar with the magnificent unity of classical physics. You have a decided advantage there, but lack of knowledge is no guarantee of success."

Pauli to Heisenberg

Introduction

For more than a decade policies guiding scientific and engineering research in the U.S. have been shaped by the desire to engage science more closely with pressing national needs (economic growth, health, well being, and national security, among others) and by the perception that doing so demands a new sort of scientist, one who is educated to integrate diverse disciplinary frameworks and methods, to communicate across sectoral borders, and to move fluidly among the worlds of research, policy, and business (COSEPUP, 1995). In response, the National Science Foundation (NSF) in 1997 made a deep and enduring commitment to integrative, interdisciplinary graduate education through the creation of the Integrative Graduate Education and Research Training (IGERT) program, which is intended to "catalyze a cultural change in graduate education, for students, faculty, and institutions, by establishing innovative models for graduate education and training in a fertile environment for collaborative research that transcends traditional disciplinary boundaries" (NSF07-540: 5). The first IGERT competition was held in 1998, with annual competitions continuing to the present. By December 2007 some 200 IGERT programs have been funded, involving about 4,200 students at a cost exceeding $200M.

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The IGERT program espouses a distinctive model of graduate education that is conducted by a varied group of faculty who share an interdisciplinary theme and offer a spectrum of innovative educational activities that integrate education with research, students with faculty, disciplines with one another, and academics with those working in other sectors (NSF08-540: 6). The program aims explicitly to develop scientists and engineers capable of working across disciplinary boundaries, national borders, and economic sectors.

The program is highly selective, at both the institutional and the individual levels.[1] In the 2007 competition, for example, more than 100 public and private universities were competing through a two-stage process (pre-proposals followed by invited full proposals) for about 20 awards of approximately $3M each that will support graduate training and related activities for a 5-year period. Most of the money will provide graduate students with a $30,000 annual stipend, tuition, and an allowance for travel, equipment, and related research expenses. With this desirable package of support faculty believe that their IGERT programs enroll a broad range of highly talented students.[2]

The importance of interdisciplinary science and engineering, the challenges of bridging disciplines, sectors, and the gap between research and its uses, and the little-understood processes that mold and launch young researchers on new trajectories combine to make the IGERT program a strategic site for research on the social organization and dynamics of academic science. In our four-year study of the IGERT program we used surveys, interviews, site visits, and social network analysis to examine program design, institutional context, student and faculty performance, and scientific innovation and productivity. From this work we have learned about the motivations and aspirations of IGERT students, the satisfactions and frustrations of their faculty, the influences of IGERT participation on students' career plans, and the networks of collaboration among students and faculty that emerge from interactions catalyzed by the program. A recent program evaluation, also funded by NSF, similarly "finds that doctoral students participating in IGERT projects receive different educational experiences than non-IGERT students…and that the IGERT program has been successful in achieving its goal of improving graduate educational programs in science and engineering" (Abt, 2006). But what remains unknown is whether and in what ways IGERT participation shapes the research process and performance of young scientists.

To address such questions, which reflect some of the highest goals of the IGERT program, we designed an experiment that challenged a national sample of IGERT students and disciplinary graduate students with an intensive exercise in focused, collaborative, integrative, interdisciplinary research design. This article summarizes initial results from this novel real-world experiment, comparing the on-site research activities and accomplishments of IGERT students with those of students trained in traditional graduate programs.

Experimental Design of the Research Charrette

The term 'charrette' has evolved from a 19th century exercise at the École des Beaux-Arts in Paris where architectural students were given a design problem to be solved within a limited period of time. When time ran out a charrette, or small cart, passed through the aisles to collect the students' work. In our adaptation of this exercise, groups were formed of graduate students drawn from IGERT programs and from disciplinary programs, presented with a research problem, and asked to design the kernel of a research proposal responsive to that problem: the conceptual framework, research questions, choice and justification of research sites, study design and data collection plan, discussion of broader scientific and societal impacts, and brief list of references. Groups were given two and a half days to produce a five-page proposal and a twenty-minute presentation, which were then evaluated by a panel of experts. The research problem, developed by the same panel of experts using a modified Delphi process, was designed to be comparative, to involve both social forces and ecosystem processes and services, and to join analysis with action or policy. A subset of the expert panel judged the presentations and proposals on-site at Snowbird. (See Appendices 1 and 2 for the problem statement and evaluation criteria.)

Design and sample

The experiment was designed primarily to compare groups formed of students enrolled in IGERT programs with those from disciplinary programs. To control for the influence of duration in graduate school we separately grouped students in the first two years of graduate school and those with three or more years of experience. The design yielded a 2 x 2 table with one replication, as indicated in Figure 1.

Figure 1
Schematic Design of Charrette

	I		***II***	
	IGERT	**Non-IGERT**	**IGERT**	**Non-IGERT**
1st year students (early)	Group A_1	Group B_1	Group A_2	Group B_2
3rd year (+) students (late)	Group C_1	Group D_1	Group C_2	Group D_2

Potential participants were solicited through a national mailing to graduate departments in the environmental sciences, broadly defined.[3] Online applications requested information about students' graduate program (IGERT or not), educational background and field of study, GRE scores, and a brief essay explaining why the student wished to participate. From 158 completed applications we chose a sample of 48 students—half from IGERT programs, half from other programs—of varied geographic, disciplinary, and institutional origin. We formed 8 groups of 6 students, each homogeneous in being composed of IGERT or disciplinary students and in graduate career stage (years one or two versus years three and beyond), heterogeneous in their inclusion of students from the life, physical, and social sciences, and balanced by gender. Each group included at least 2 men and 2 women; in all, 23 men and 25 women took part in the study.

Conduct of the charrette

The charrette took place from August 24 to 27, 2006, at the Cliff Lodge in Snowbird, Utah. Participants arrived Thursday afternoon, and the study began that night with a plenary dinner, an overview of aims and plans, a review of researchers' ethical obligations and participants' rights, and brief group meetings where they became acquainted with one another and with the research problem. Work began in earnest Friday morning and continued through noon Sunday, followed by a plenary with group presentations and expert questions and commentary.

In its work room, each group found a round table, chairs, a sofa, computers, Internet connectivity, flipchart, tablets, and pens. Each room was also equipped with a video camera that recorded activities at the table, three microphones distributed around the table to capture discussion, and a trained observer who kept notes as unobtrusively as possible. Observers were instructed to limit their interaction with group members and were provided with a protocol that asked them to attend to matters of group socialization, identity formation, interaction patterns (leadership, challenges, exclusion), communication (especially cross-disciplinary questioning, explanation, and understanding), and skeptical or evaluative comments about ideas or research plans. Observers made systematic notes on a structured rating sheet every 20 minutes and made continual free-form notes of group process.

The panel of experts who discussed proposal presentations at the Sunday afternoon plenary and rated the written versions during the following several days was composed of three ecologists, an atmospheric scientist, a mathematician, an economist, and a marine management official. During the plenary, the panel questioned presenters and offered comments and advice. After the plenary the experts provided written evaluations to the participants and to the researchers. Experts also rated fifteen aspects of the proposals, using criteria and five-point scales (1=poor to 5=excellent) that they had helped us to adapt from the work of Veronica Boix Mansilla and her colleagues (in press). Table 1 presents an abbreviated version of the items, organized into the scales that will be reported below.

Table 1
Proposal Rating Items and Scales

Intellectual merit (1 item): per NSF criteria
Broader impacts (1 item): per NSF criteria
Disciplinary quality (4 items): grounding in disciplinary literature, effective use of knowledge, description of methods, depth ($\alpha = .89$)
Interdisciplinary quality (5 items): use of diverse literatures, integrative framework, synthesis, breadth, comprehensiveness ($\alpha = .96$)
Scientific reasoning (4 items): originality, problem formulation, skepticism, rigor ($\alpha = .80$)

Expectations and Results

We expected IGERT student groups to outperform disciplinary groups on all dimensions among both junior and senior graduate students, and we expected the magnitude of the IGERT-student advantage to increase with time in graduate school, reflecting more effective integration and synthesis of a growing body of knowledge as well as increasing facility with multidisciplinary collaboration and translation between scientific problems and real-world applications of knowledge. Our expectations are based on IGERT projects' ability not only to attract students with aptitude and interest in integrative interdisciplinary research, but also to reinforce and develop those qualities through a spectrum of educational, research, and training activities. Both the Abt evaluation (2006) and our own research support these expectations.

For example, the Abt study finds that IGERT graduate students are more likely than their disciplinary peers to report having experience with multidisciplinary research projects (76% versus 42%), team research projects (66% versus 50%), research projects with students from other disciplines (64% versus 36%), and training in communication outside the student's home discipline (50% versus 22%; Abt, 2006: 33, 35). In consequence, IGERT students are more likely than their disciplinary counterparts to feel very well prepared to work in multidisciplinary teams (42% versus 19%) and to communicate with people inside (52% versus 41%) and outside (34% versus 13%) their fields (Abt, 2006: 34, 36). Further, IGERT faculty rate IGERT students as more capable and promising than disciplinary students (see fn 2). Based on such traditional measures of program character and performance, we would agree with the Abt report conclusion that "IGERT graduates enter the work force better prepared for the science of the future in the careers of the future" (Abt, 2006). But whatever differences there may be in student composition, program content, self-reported preparedness, and satisfaction, the consequential question is whether and in what ways educational experiences change how young scientists work together and the quality of what they produce.

Given our exercise focused on interdisciplinary team problem-solving, we expected IGERT student groups to outperform groups of students from traditional disciplines, and for the difference to be greater among experienced students than among students in the early years of graduate school. As Table 2 shows, our expectations were only partly supported.

Table 2
Mean Facet Ratings for Each Group, by Seniority and IGERT Status

		Intellectual Merit	**Broader Impacts**	**Disciplinary Quality**	**Interdis. Quality**	**Scientific Rigor**
First or Second Year	**IGERT (mean)**	3.0 4.0 (3.50)	3.2 3.5 (3.35)	3.1 3.6 (3.35)	2.7 3.6 (3.15)	3.2 3.5 (3.35)
	NOT IGERT	3.0 3.0 (3.00)	3.0 3.0 (3.00)	2.9 3.1 (3.00)	3.2 2.9 (3.05)	2.7 3.2 (2.95)
Third or Later Year	**IGERT**	2.0 3.0 (2.50)	2.3 3.5 (2.90)	2.5 3.2 (2.85)	2.3 3.1 (2.70)	2.3 3.3 (2.80)
	NOT IGERT	3.0 3.0 (3.00)	3.5 3.0 (3.25)	3.4 3.0 (3.20)	3.7 2.9 (3.30)	3.3 2.8 (3.05)

Among students in the early years of graduate study, proposals prepared by IGERT groups received higher average scores on every dimension than did proposals produced by non-IGERT groups. Among experienced graduate students, however, the pattern is reversed: rather than the increased advantage for IGERT students that we anticipated, we found instead that on all dimensions non-IGERT students outperformed IGERT students by amounts ranging from 0.60 to 0.25, averaging nearly 0.40. The highest scores for all groups on all dimensions were obtained by an IGERT group in its early years of graduate study, and the lowest score of all groups on all measures were given to a senior IGERT group.

Since these results are based on a small sample drawn by self-selection from a population with unusual dimensions and formed into groups using a mixture of random assignment and quotas, most statistical tests are inappropriate. In their place we offer other ways to assess the soundness of these results. First, the results are not an artifact of ability, as measured by the GRE. Table 3 shows virtual equality of average group scores across all four categories.

Table 3
GRE Scores by Seniority and IGERT Status

	IGERT	**Non-IGERT**
First or second year in graduate school	V: 621 Q: 700 T: 1321	V: 602 Q: 697 T: 1299
Third or later year in graduate school	V: 610 Q: 708 T: 1318	V: 622 Q: 697 T: 1319

Second, the results are remarkably consistent across scales, constituent items, and raters. Appendix 3 shows that on 13 of 15 comparisons the IGERT groups outscore the non-IGERT among the first- and second-year students, but that the opposite occurs among senior graduate students.

Third, the results are robust: if the junior IGERT group with the highest overall score and the senior IGERT group with the lowest overall score are excluded from consideration, which removes the strongest support for the principal finding reported here, the remaining six groups show the same pattern: among junior students, the remaining IGERT group has the top score (alone or in a tie) on 4 of the 5 scales, whereas among senior students, where we expected IGERT students to have a greater advantage than they had in the earlier years, the remaining IGERT group does not excel but is tied for highest score on three scales, in second place on the other two.

The experimental results are substantial in magnitude, consistent in direction, and robust to reasonable challenges. Recognizing the limitations of the study—a one-shot design in a single domain, a small and self-selected sample in unusual surroundings, performing a creative task that imposes distinctive demands on group interactions their interaction—we provisionally accept the results and address their possible causes and implications.

Discussion: Implications and Limitations

One possible explanation for these results is that IGERT programs are often immersive at the outset, involving students deeply in educational and extracurricular activities in the early years of graduate study (in fact, some begin with an outing or retreat during the summer before the first year of graduate study). Thus, students might be strongly influenced by the program in their early years, but the level of activity declines and its influence attenuates over time. As this attenuation occurs, the disciplinary empire strikes back, reasserting itself in the form of qualifying exams, dissertation proposal requirements and evaluations, the dissertation itself and its defense, with their demand for disciplinary depth and technical facility, and the prospect of a discipline-dominated job market. After a brief but pleasant immersion in pools of interdisciplinarity, the senior student encounters the more treacherous waters and institutional realities of a newborn professional career. Advanced graduate students may become more self-consciously disciplinary and less sanguinely interdisciplinary than they may have been earlier on.

In addition to being a complicated professional endeavor, interdisciplinary research is a complex intellectual enterprise. Disciplines are so named for a reason: in addition to disciplining members (and candidate members) through a spectrum of sanctions, they also discipline thought through the concepts, methods, and standards—the epistemic cultures—taught to prospective members and institutionalized through review practices, hiring standards, and promotion criteria. As a student advances through training, the student becomes immersed in the epistemic culture of the discipline, which begins to shape his or her view of the research landscape. In fact, the latency and force of disciplinary cultures asserted later in the graduate career may supplant early interdisciplinary experiences by seeming more tangible, more real, more hard-headed and scientific.

If such processes are at work, perhaps interdisciplinary graduate education would be enhanced if students first acquired disciplinary concepts, knowledge, methods, and epistemic standards, then learned ways to relax and recombine them into interdisciplinary patterns of inquiry and understanding. Research in the cognitive sciences has revealed the importance of understanding how knowledge is organized and structured within a STEM field to one's ability to achieve adaptive and flexible problem solving within and across domains (*2*).

Or, perhaps, an educational model that oscillates between disciplinary and interdisciplinary phases would work best, allowing the material taught to be integrated by parts. Either would allow fluid interdisciplinary responses to disciplinary assertions, depriving disciplines of the power of the final word in the student's career.

If such are explanations are correct, they also pose a clear implication for programs designed to develop interdisciplinary scientists and engineers. The implication is that support only in the early years of graduate education will likely be insufficient to effect the transformations that motivate the IGERT program. Additional resources, applied throughout the graduate career, will be required for graduate students to withstand the countervailing disciplinary forces they will face in their doctoral programs. And as the student enters the early career, confronting disciplinary journals, disciplinary funding opportunities, and departmental (read, usually, disciplinary) standard for renewal, promotion, and tenure, ongoing support will be needed to transform investments in interdisciplinary graduate education into new knowledge and new modes of inquiry.

And while many of these barriers to successful interdisciplinary research and education programs are organizational, we should not neglect the cognitive and developmental processes that shape how people learn, think, and innovate. The challenge is to understand in what ways and at what time in a scholar's professional and intellectual maturation it is safest and most effective to dive into the pools of interdisciplinarity.

References

Abt (2006). *Annual Report and Summary of the Cross-Site Monitoring of the NSF Intergrative Graduate Education and Research Traineeship (IGERT) Program.* Alina Martinez, Anne Chase, Jennifer Carney, Beth Boulay, Deepika Chawla, Carolyn Layzer, Lisa Litin, Natasha Zotov, Sharon Goldsmith, Don Haviland; with the assistance of Mary Ann Millsap, Jan Nicholson, Sarah Pollack, Katheleen Linton (February).

Boix Mansilla V. Dawes Duraisingh L. Wolfe C. & Haynes C. (2008) 'Targeted Assessment Rubric: An Empirically Grounded Rubric for Interdisciplinary Writing.' *Journal of Higher Education* (in press).

COSEPUP. (1995). *Reshaping the Graduate Education of Scientists and Engineers*. Washington, DC: National Academies Press.

Appendix 1

Snowbird Charrette in Environmental Research Design

PROBLEM STATEMENT

Ecosystem services of various sorts (e.g., purification of air and water, mitigation of floods and droughts, detoxification and decomposition of wastes, pollination of crops and natural vegetation, partial stabilization of climate, soil fertilization, maintenance of biodiversity, and such) are vital for the lives of humans and other species as well as for the continued viability of ecosystems. However, considerable evidence is accumulating to suggest that changes in climate, land use, and other human activities may be altering the performance of ecosystems and the services they deliver.

Your challenge is two-fold. First, pose a scientific question concerning the interaction of human activities and one or two specific ecosystem services. Then, propose the best "next generation" research plan to analyze this question in two strategically chosen geographic sites that have comparatively different levels of human activity (e.g., (a) urban coastal zone such as New Orleans or Shanghai; (b) mixed use zone such as Chesapeake Bay or Baja, California; (c) rural arid zone such as Patagonia or western Gobi, etc). The ecosystem services you consider for your question and in the design of your study at each site should come from the list developed by the Millennium Ecosystem Assessment (see attached).

In your proposal please include the following six elements: (1) a conceptual framework for understanding and analyzing the interactive processes at work; (2) a set of testable hypotheses or research questions derived from the framework; (3) a brief description and justification of the strategic research sites where the hypotheses/questions will be tested; (4) a data plan for testing the hypotheses/questions in the chosen sites, complete with a description of methods (e.g., field experiments, social science surveys, computer-based predictive analyses), hypotheses, and analyses that will shed light on essential elements and dynamics of your framework; (5) a discussion of the broader impacts of your research for policy, resource management, and decision making; and (6) a list of at least 15 references essential to shaping your design.

Your goal is to design a study that will yield the clearest understanding of the human activities-ecosystem services interactions specified in your question within and across your two selected geographic sites. In so doing, please propose a combination of empirical work to test proposed relationships and computational/ statistical/mathematical modeling to extend them in space or time, and quantify the uncertainty associated with the resulting explanations and predictions/forecasts. In your empirical tests and models please be certain to discuss the sources and types of data that you would need to collect and how you would go about obtaining them. Since your aim is both to advance fundamental scientific understanding and to have broader relevance for environmental management, policy and decision-making, please design your study not only to produce well-grounded empirical findings but also to yield original insights into the key social and natural processes.

Your proposed research should be novel and original in both the approaches it deploys and the insights it yields. And, though you need not provide a detailed literature review, indicate clearly how your proposal is original yet builds upon existing research approaches. We are not asking you to develop a budget or management plan for this research, but would like to orient your thinking toward a project that would cost roughly $2M per year for five years. In general terms, these resources would provide for example, a research team of about 3 to 5 senior (faculty- type) investigators, 3 to 5 postdoctoral fellows, about 10 graduate students and/or technicians, and 20 part-time undergraduates, and rental access to facility class instrumentation and computation (e.g., isotope mass spectrometers, research vessels and aircraft, parallel computing facilities), and all of the materials, supplies and travel characteristic of a well-funded research team. Please consider these loose resource guidelines and allocations as budget possibilities not budget limits. Their purpose is simply to help anchor your thinking.

Appendix 2

Snowbird Charrette in Environmental Research Design

PROPOSAL / PRESENTATION REVIEW FORM

The proposal/presentation should:

- *Be research oriented*. Student teams will be developing a scientific research proposal, not, for example, designing or making an object or tool to undertake some task (as in the many extant "robot design" competitions).
- *Be open-ended*. The problem should not have a single or a best solution, but should admit any number of approaches.
- *Be concrete*. The problem's open-ended quality should not mean that it encourages idealized, abstract, ungrounded, and/or speculative responses. Rather, it should lead students to produce a research design that is specific as to scale and site, and it should be framed to push student teams to generate tangible questions with definite practical research implications.
- *Have societal implications*. The problem should somehow explore the intersection of natural and human social dynamics rather than being a "pure" environmental science problem.
- *Draw from skills from across the environmental sciences*. Each team will have an interdisciplinary membership (some teams will have students that were all trained in interdisciplinary IGERT programs and some will have students from disciplinary programs), but in both cases students will come from a mix of disciplinary backgrounds. Thus, the problem must be open enough to allow students with any kind of training in a research area intersecting the environmental sciences to make a contribution without systematically advantaging or disadvantaging any particular combination of methodological or content expertise. The problem should enable experimentalists, modelers, empiricists, and theorists to each have a stake in the process. We will be interested to learn how each team leverages the diverse training of its members.
- *Be open with respect to reliance on the scientific literature and other sources.* Whether and how students choose to rely on the scientific literature in their proposals, and which literatures they draw from could be an important source of variation between groups. Thus, the problem should enable different choices and strategies viz. prior scientific resources. This will enable us to evaluate their research proposals in terms of their originality vs. continuity with respect to existing research traditions. We should consider providing all teams with any resources (maps, articles, data, etc.) that are deemed necessary for engaging the problem.
- *Be open as to how teams can draw boundaries around the problem*. The problem should not predetermine project parameters or elements students may choose to include in their proposals. Students should be free to determine for themselves what are the "core" issues of the problem, how much they can feasibly propose to study, how deeply and broadly they direct their engagement, and which "variables" to engage and which to ignore. We want to understand whether there is a relationship between students' interdisciplinary training and how they manage trade-offs between breadth and depth of research, intellectual ambition and practical feasibility, and choosing methodologies and research strategies that are reliant on prior approaches or that are responsive and effective to conditions particular to the problem.
- *Be open to different ways of dividing up tasks and topics.* The problem should avoid either implicitly or explicitly dividing up the topics or tasks for the students. Because we seek to understand variations in how students allocate tasks and integrate knowledge in interdisciplinary collaborative environments, we want them to have to choose how they disassemble the problem, divide labor, and design a scientific response. For example, do they divide the problem into "discipline-specific" pieces, work separately, and produce a modular proposal, or do they, perhaps, find a framing of the problem that allows them to work collaboratively, simultaneously, and develop a proposal with little discipline specificity.

Appendix 3

Mean Ratings of Proposals on Specific Quality Dimensions By Seniority and IGERT Status**

Rating for individual criterion	First or Second Year Non-IGERT	First or Second Year IGERT	Third or Later Year Non-IGERT	Third or later year IGERT
Intellectual Merit What is the proposal's potential for advancing scientific knowledge and understanding of the problem?	3.00	3.58	3.08	2.75
Broader Impacts What is the proposal's potential for affecting policy and decision making? Does the proposal address potential benefits to society?	3.08	3.33	2.75	2.58
Disciplinary Literature Is the proposal well-grounded in disciplinary works that are relevant to the proposed study?	2.33	2.83	2.42	2.42
Disciplinary Knowledge Does the proposal accurately and effectively use disciplinary knowledge (e.g., concepts, theories, perspectives, findings, and examples)?	3.58	3.92	3.75	3.25
Disciplinary Methods Does the proposal accurately and effectively propose the use of disciplinary research methods (e.g., data collection, analysis, validation)?	.3.00	3.17	3.41	2.92
Depth	3.08	3.50	3.25	2.75
Interdisciplinarity Does the proposal draw from different disciplinary literatures relevant to the proposed study?	3.08	3.08	3.17	2.67
Integration Does the proposal address a holistic topic and present an integrated framework to approach to that topic?	2.92	3.17	3.33	2.33
Synthesis Is there a sense of balance in the overall composition of the proposal with regard to how the disciplines are brought together?	3.00	2.83	3.17	2.50
Breadth	3.25	3.42	3.50	2.83
Comprehensiveness	3.08	3.33	3.42	3.17
Proposal Formulation How well-conceived and organized is the study as scientific research proposal?	3.08	3.67	3.42	3.08
Scientific Skepticism Does the proposal and/or presentation demonstrate an understanding of the study's strengths and weaknesses?	2.08	2.33	2.17	2.25
Rigor	3.17	3.50	3.25	3.08
Originality	3.42	3.83	3.25	2.75

***This rubric has been adapted from the original rubric created by and currently under testing by Veronica Boix Mansilla, Liz Dawes, Carolyn Haynes & Chris Wolfe at the Harvard Interdisciplinary Studies Project. While HISP seeks to apply their original version of this rubric to high school and undergraduate writing assignments, they have agreed to "loan" it to us for modification and use for the assessment of graduate student research proposals.*

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[1] "Selective" here in a precise way: for IGERT projects, a very large number of pre- and full proposals is submitted to yield a small proportion of awards: roughly 10% of pre-proposals result in awards. For IGERT students, we do not compare academic records and test scores but use the term "selective" to characterize the exacting process IGERT projects reported to us that they used to choose students. On-site interviews with current students were common in established programs, and such interviews entailed some probing for the distinctive qualities that students and faculty believe make for successful IGERT students.

[2] The Abt study reports that 85% of IGERT PIs and 72% of department chairs surveyed believe that IGERT grants allow them to recruit more highly qualified students. Among IGERT faculty, 75% "believe that the students in the IGERT program are better qualified than the usual department students in terms of their academic and research potential…. IGERT faculty rated their IGERT students as "Far superior" (16 percent), "Somewhat better" (59percent), "About the same" (21 percent), or "Somewhat less promising (4 percent) (Abt report, p. 67). Our survey results agree: IGERT faculty believe their students are more capable than traditional departmental students. GRE data do not concur: on verbal (576 to 619), quantitative (713 to 738), and analytic (692 to 737) scales IGERT students scored lower on average than their disciplinary counterparts (Abt, p. 68; we did not gather GRE data from the overall student population).

[3] A poster inviting students to apply for the charrette was mailed to nearly 600 graduate programs and departments related to the environmental sciences but which may emphasize earth, ecological, or social science disciplines. Some were IGERT programs but most were not. Programs were identified using the Peterson Guide to Graduate Programs (2006 edition) and controlling for doctoral institutions (I & E) per Carnegie Classification. More than 200 applications were initiated online and 158 were completed, each providing background information about the student, GRE scores, and a brief essay explaining why the student wished to participate.