

Innovative, Integrative, Interdisciplinary Graduate Education and Training: New Concepts for Assessment

Second Interim Report to IGERT Program Directors

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This report is the second in a series of Interim Reports to IGERT Program Directors. These reports are part of an effort to keep IGERT participants informed of the findings from our NSF funded research project called, “Innovative, Integrative, Interdisciplinary Graduate Education and Training: New Concepts for Assessment.” This project is conducted under the direction of Dr. Diana Rhoten (Social Science Research Council) and Dr. Edward Hackett (Arizona State University).

This Second Interim Report is designed to give IGERT directors an overview of some the preliminary findings from interviews conducted with PIs, Co-PIs, administrators, faculty, and graduate students across different IGERT programs over the last 12 months. This Report is organized into six sections, based on key themes identified in the interview data, including: (1) What is Interdisciplinarity, (2) Aspects of the Interdisciplinary Mindset, (3) Creating Cohesive Communities, (4) Problems with Community, (5) The IGERT Stipends, and (6) Differences in Faculty and Student Perspectives. Ongoing interviews and site visits will seek to confirm, expand, and elaborate the early data presented below.

(1) What is Interdisciplinarity?

One purpose of our project is to learn how faculty and students engaged in interdisciplinary research and education actually conceive of and practice *interdisciplinarity*. Social scientists, educators, philosophers and others have long debated the definition of interdisciplinarity, its implications, pros, and cons. But very few studies have actually taken the step of analyzing interdisciplinarity empirically by interviewing and observing scientists who engage it. We suspect this is the case, at least in part, perhaps because interdisciplinarity as a concept is complex and notional rather than clear and definitional, making it difficult to capture and measure. Thus, our study began by analyzing the interpretations of interdisciplinarity that emerged from the field, rather than by applying designations from the literature to the data.

One of the most common understandings of interdisciplinarity circulating in the IGERTs we have visited to date involves the exchange of tools, practices, questions or the interaction of scientists from two or more different well-institutionalized disciplines. This sense of interdisciplinarity—which we are calling *cross-disciplinary exchange*—was the starting point for many of our respondents. Some interviewees, such as the faculty member below, reported dramatic results from this form of interdisciplinarity.

Probably the most dramatic impact [of the IGERT program on me] has been on the idea of experimental design. Atmospheric chemists are sort of at the Darwin’s cruise on the Beagle stage. We go out fishing, we’re collecting samples, we’re cataloging and archiving. And I would argue that much of that is not science. It’s not reasoning process from pattern. It’s not drawing inferences or hypothesis testing. And so there are people who say “I’ve got an instrument, I’m

going to go out and use it. I don't know why I'm going to measure things, but no one's ever measured it before, so I can get a paper out of it." And that's not really science. But it's important work. Darwin couldn't have written *his Origin of Species* if he hadn't gone out and collected all these samples. So it's important work, but it's so much more intellectually satisfying to me to have a clear hypothesis that can be tested using techniques that we know. Which is the way that the ecologists have worked all the time over here. I guess I hadn't seen that distinction because in chemistry, of course, we do hypothesis testing, but we don't do the kinds of experimental design, the really clear elucidation of null hypotheses that the ecologists do.

According to this respondent, apart from the high-tech equipment, atmospheric chemistry is like natural history in that its experiments are really about collecting and classifying. By interacting with biologists, however, the respondent has come to understand his field's research this way and has learned how to design, execute, and write about experiments using a "more scientific" hypothesis testing mode. For this speaker, then, the cross-disciplinary exchange version of interdisciplinarity has resulted in the importation of experimental practices from one discipline to another, having a revolutionary impact on the receiving domain.

Many respondents, however, are not fully satisfied with the cross-disciplinary exchange variety of interdisciplinarity as the end goal, and want to add to or go beyond it. One PI, for example, discussed the progress of students to become interdisciplinary researchers:

They're not the single disciplinary // their focus is changed and they are // I mean partly it's a function of really understanding enough of the other disciplines and becoming articulate, having a vocabulary, getting comfortable. *But I think it's more than that.* Because you can read the literature, you can go to the fundamentals workshops, and some people will come away and they look to me as if they've done the same as sitting in a seminar once a week during the academic year and having no other immersion aspect. And other people look to me like they've come out of a Berlitz program and they're different. [emphasis added]

Thus, for some faculty like this one, cross-disciplinary exchange seems to just the starting point of interdisciplinarity, which in its full form represents something akin to learning a whole new language—perhaps a whole new culture. This second version of interdisciplinarity, according to respondents, has to do with what we are calling the *interdisciplinary mindset*, a "new way" of thinking.

Ironically, while PI's and faculty, like the one below, often identify the interdisciplinary mindset as something they seek to foster via the IGERT, when asked to identify its component attributes, they have difficulty describing what traits, attributes, and skills necessarily represent this accomplishment.

... it's not a measure I can articulate. Basically, they are expressing // their thinking's different. They're thinking differently, they just are. When you have a conversation with them it's not single discipline. They're taking into account lots of things they've learned. They're maybe talking about something that's an atmospheric phenomenon but are talking about it in the context of what's going on between the biosphere and the atmosphere exchange. There's something, it's just, it's just different.

What gives this problem teeth is the fact that, despite their inability to identify what the interdisciplinary mindset is beyond a "cluster of symptoms," so many PIs have staked their tacit, and often official, senses of program success on developing this interdisciplinary mindset in students: "I think that's how I measure success ... Are these people emerging as interdisciplinary thinkers? Are they likely to be leaders in the future? Do they have the capacity or the interests to do that?" Below, we try to unpack this concept a bit more in an effort to help advance our general understanding of this concept, how to identify it, foster it, and manage it.

(2) Aspects of the Interdisciplinary Mindset

Despite the difficulties that IGERT members have articulating the interdisciplinary mindset, there are many ideas floating around IGERTs that might bear on the issue. Students especially, in talking about their own cognitive inclinations and the kinds of characteristics that they see as key to success as an IGERT student, offer many suggestions that PIs and others might explore when thinking about the cognitive capacities they are seeking to nurture.

Quite frequently IGERT members, both students and faculty, emphasize that a successful interdisciplinary researcher cannot be easily predicted by conventional metrics. While discussing a student she considered a strong interdisciplinary thinker, one PI commented, for example, that “there was a lot that was very attractive about her [in her application]. But she wasn’t that strong, her test scores, her grades weren’t all that good....in fact a lot of our students haven’t been off the charts [in this respect]. It’s been very interesting.”¹ Many of these students, she continued, go on to be quite successful in the program despite what might be considered shortcomings on traditional aptitude performance measures, leading her to believe that criteria other than just grades and test scores might be better indicators of one’s capacity for interdisciplinary work. Another PI claimed that, even though her program is in “a big public university without that name cache,” her program is competing with schools like “the MITs” for “top-tier”—and conventionally recognized “top-tier”—students.

Similarly, when asked about the keys to success in IGERT programs, students, like the one below, also tend to downplay traditional measures of intelligence and knowledge in their representations of their ideal.

So the thing that most impresses me about a new IGERT person, I usually assess them not by their prior knowledge but how quickly they can pick up new knowledge....*So adaptation and I think being, it doesn’t really have anything to do with being smart, it’s just being able to understand new ways of looking at the research you’ve been trained to look at for a while.* Some people don’t do that very well, and they go on to have extremely successful careers in their field. Their own microcosm. That doesn’t work here.

Another student reinforces the theme of adaptability and mental flexibility, describing the secret to success almost in terms of what might be considered *learning to learn*:

Well you have to be able to handle a lot of disparate information, especially when you’re starting out, at not a very detailed level. And you have to recognize what you’re not understanding and learn that quickly or figure that out.

Faculty and students report that students in IGERTs work extremely hard, often having to conquer a significant amount of factual knowledge as well as master two or more intellectual approaches or cultures. Thus, truly acquiring an interdisciplinary mindset requires being not only a quick learner but also a strategic learner. Reading, processing, memorizing more pages per hour is not sufficient; one needs to “know what you don’t know” quickly and then figure out how to learn it.

What gives this cognitive capacity its particular urgency is the acute anxiety that many IGERT students feel about the balance they have to strike between specialization and breadth. As one respondent explained:

¹ One fairly common complaint by PIs about student quality concerns insufficient mathematical training.

I think it's a common experience that you're confronted by all these disparate disciplines, and you're gonna' be deficient in one thing or another. And, and it's, it's like, can you be a master of all trades, you know, or are you gonna' just be a jack of all trades, a master of none? I... it's hard to know.

A key element in developing one's interdisciplinary mindset, then, according to students, is *self-motivation*, the willingness to do more than is technically required of you by the program. One respondent summed this up by saying:

I've seen a lot of the people who would be in this program, who do something and realize they don't have a particular strength. And they go and take a course [in that area]. It's not required by the program, it's not required by their department but they still go and take it.

In the same manner, this same speaker quoted above, when discussing the need to handle information and recognize gaps quickly, added:

I would like to say that everybody can do that, but I think there are people that can't or at least aren't ready to do that. We have some undergrads in our [program] classes and maybe even a couple of graduate students. And they don't invest enough time to see the connections between the different concepts or how to put them together, and why that's important.

As in all graduate education, hard work and commitment are critical to success. But, in the IGERT programs, students do not process these traits to mean "doing everything your advisor tells you to do" or doing all the extra problem sets and optional readings on the syllabus. Rather hard work and commitment mean exploring and developing one's own *intellectual breadth*, particularly and especially when it may fall outside of the usual, well-marked path. A number of students described this ethos. One student said, for example:

I try very specifically to not let that happen [getting "caught up in the detail"]. I read the newspaper. I try to walk out of this building [laughs]. Try to be aware of things going on in science, things that are going on in the world, things that are going on in the government, technology, pharma, biotech. I try to have my eyes open to things;

another said,

I like being, you know, the Chemical Engineer who could write, or the English major who knows how things work, so, sort of, trying to be, be a... trying to learn everything. (laughs) If possible... you gotta' try sometimes.

Students also demonstrate this ethos by seeking to distinguish themselves from those they see as narrowly focused and unwilling to venture outside their own area of expertise. One student contrasted his outlook with that of other students whose discontent with the IGERT program he interpreted was the result of their relatively single-minded or myopic foci:

Some people in the IGERT program, they complained a lot because they knew exactly what they wanted to do coming in. And they were trying to do it, but they have to go to these, you know. they have to go to colloquium, or they have to take this class and do this stuff that they know is never going to fit in. For me, it's been really nice because I've been able to pick and choose topics from seven or eight different disciplines and see how they relate to what I want to do.

Thus, these students above, like others in our sample who report taking well to the IGERT program, tend to see the various IGERT courses and requirements as fruits to pick rather than rivers to cross.

Another dimension of a researcher's interdisciplinary mindset, also linked to the ethos of breadth and exploration, is distaste for the concerns perceived to be at the "center" of disciplines. The following examples from graduate student respondents are illustrative:

[My research] will be coupled to a real life messy problem. Both because it is a real life messy problem, and also because I haven't deduced it down to this simple problem. So I have to get the community to accept that as a problem. And, really, I don't know if I want to do that. That's sort of why I don't want to be a computer scientist. I don't want to have to prove things mathematically, that it always behaves this way. I'm more interested in finding something out about the system;

and,

There's plenty of faculty [in my department] that have no idea // they don't think about environmental questions; they don't even think about microbial questions. They think about very // where does this electron go? So, I'd say, that's a personal thought, there are some people that do. But I'd say the majority don't care to understand it.

Thus, these students, like many respondents, describe their research and intellectual interests by counter posing them against the mainstream concerns of the disciplines or departments in which they had or were currently receiving training. More than IGERT faculty, IGERT students in particular were inclined to describe disciplines in terms of their supposed narrowness, “nitpicking”—or highly technical—concerns, and their parochial lack of interest in “big picture” questions. IGERT Faculty members rarely described their disciplines in such disparaging terms, perhaps because they feel comparatively less compelled to distinguish themselves in this way or because they were more likely to be brought up in as well as “bought into” disciplinary life in contrast to most IGERT trainees.

Interestingly, in contrast to Rhoten's previous study of interdisciplinary programs,² we have found comparatively less evidence in this study to suggest that students choose interdisciplinary programs because they are more committed to “socially responsible” science. Those who did voice this motivation—“I also find it fulfilling to be doing something that I believe is to the greater good”—tended to be in biology programs, where the research they were doing might one day contribute to disease cures. Perhaps this kind of motivation goes without saying among scientists in the broad environmental sciences or engineering programs, but few of them explicitly voiced these aims like this environmental engineering IGERT student below:

When I first started [my research], I was really scared. But, I needed to find a way to work at the interface of chemical engineering and microbiology, or I needed to find a different question. It was obvious to me, taking on the remediation of chromium and arsenic from the water supply was more important than my giving into my own fears. ... So, now, I am sorta' on the fringe of science, I guess. But, I am dealing with the core problems of society. So, yeah, that is where I want to be.

Indeed, one faculty member even voiced dismay that his students did not share the “lofty idealistic.... save the world idealism” that he claimed had originally motivated the program organizers. Thus, insofar as IGERT students are concerned with “problem oriented” research, this may imply less of an affinity for “socially conscious” research than it does for “intellectually complex” challenges that are arguably difficult to solve from a single disciplinary perspective.

Respondents reported that a number of cognitive orientations help them tackle the difficult problems of interdisciplinary research. In addition to the ability to explore, develop, and connect disparate types of information, an interdisciplinary mindset also demands a comfort with complexity and ambiguity. As one PI put it, “I think it is a really rich intellectual territory and

² Rhoten, D. Risks and Rewards of an Interdisciplinary Path. *Science*. (December 17).

there aren't simple answers. I am happy with that; I don't need to have the 'right' answer." Other respondents pointed to a holistic perspective that distinguishes them from other scientists:

And so, you know, I walk out in the forest and, you know, if I walk out with a soil person they're looking down, the tree person is looking straight, and the atmospheric scientist is complaining that trees are blocking the sky, you know. But I, you know, I'm, I'm looking at it all, I'm seeing a more integrated system. So maybe that's it, you know, it's, it's trying to get—to step back and see a bigger system happening as opposed to... yeah, sort of doing more of a wide, fish-eye lens than a microscope zoom.

This speaker, a graduate student, pushed the point further by invoking an intellectual division of labor that places the interdisciplinary thinker in what he sees as a particularly privileged position:

I can't say [the interdisciplinary outlook is] more useful, because obviously you need everybody looking at their own little parts before somebody can assemble them, but I do like being the one that steps back and sees this flow into this, which flows into this.

This outlook is sometimes cast even in moral terms; the interdisciplinary mindset itself viewed as a corrective to some of the specialization accompanying social and intellectual change:

The way that I perceive human evolution in the last couple hundred years, we went from everyone living individually in little villages and stuff and not a lot of specialization to making huge leaps and bounds in quality of life with economies of scale and specialization, to making, along the same lines, great scientific and technological advancements in knowledge and understanding based on specialization. And now it's time to step back out and weave the web together a little bit better.

It is interesting to note that in these last few quotes particularly, as well as those preceding them and the interviews more generally, speakers are much more inclined to talk about interdisciplinarity in terms of getting the "big picture" and other metaphors that are much more about mental "holism" and intellectual "integration" writ large than about practical "mixing and knitting" or epistemological "borrowing and trading" of specific disciplinary components. Thus, while it is too early for us to specify further or explain this choice of metaphors, this conscious or subconscious representation of interdisciplinarity certainly resonates with our earlier observation that "cross-disciplinary exchange" is viewed as merely the gateway to whereas the "interdisciplinary mindset" is perceived to be the real destination integrative graduate training.

Both articulating and nurturing the "interdisciplinary mindset" is difficult as our interviews indicate. Interestingly, the "cross-disciplinary exchange" that respondents often describe as less important is a significant outcome of the ways in which IGERT programs are organized. In particular, there is a lot of evidence suggesting that IGERTs are doing much to build *communities* capable of supporting vigorous cross-disciplinary exchange. In interviews, community building often seemed to be of secondary importance compared to individual cognitive achievements, but the production of healthy, well-integrated communities was a major achievement of the IGERTs we have visited. To this matter we now turn.

(3) Creating Cohesive Communities

One of the major successes apparent in the IGERTs we have visited thus far is their ability to build a robust interdisciplinary community of scholars. In some cases, the task was not so difficult because PIs used the IGERT to reinforce a previously existing social network or to bring together departments between which strong connections already existed. However, others worked at the opposite extreme, bridging far-flung departments, programs, schools, even

universities—no mean feat given the vast size of most research universities. One graduate student was very attuned to this issue:

IGERT...It's kind of the glue that's missing when you talk about [University] and the different departments....That's the value [of IGERT], right? Having a cohesive community within a university that is spread out so much. [University] is a hard thing to get a grasp on in terms of bioinformatics research because there's so many different departments and they're so spread out.

Though promoting camaraderie and unity is not usually described as a primary program goal, PIs and others responsible for the program often gushed in their descriptions of the student communities they had helped create. This is exemplified in the remarks of one IGERT administrator.

Respondent: But there was just a certain culture to the program, especially in the early years that just bred the nicest, smartest really wonderful students.

Interviewer: Do you think it drew those students or developed them?

Respondent: Both, it was a whole culture. They were treated well, and they reciprocated.

It is noteworthy that this student brought this up almost as an afterthought to the interview when she was asked for any final thoughts. A faculty member of a different program offered another strong description of the same phenomenon:

what really strikes me, again, they might not know it's unique, they have no concept because they don't know any different, but they have a social community that involves the geoscience students mainly, both [IGERT] and non-[IGERT], but it also has brought in non-geoscience graduate students from biochemistry, cell biology, biology, basically from across campus because of [program]. It's very clear who exactly's in [program]. They're a part of the same social scene.

A co-PI from this same program also underscored this theme of strong community—focusing on connections in terms of opportunity rather than social cohesion. In so doing, however, she wondered whether the uniqueness of these opportunities had become “taken-for-granted advantages” of an IGERT, especially for those participants who have no other frame of reference against which to compare an IGERT to “typical” graduate training.

I had a friend come in once who interviewed our [program] students. She's a dean at [University] or something, and she asked them, “What's good about your IGERT? Is it just the money—I mean, obviously the money is good—but does it change your life in any way?” And there was only a handful of students who were saying, “Oh, I don't think it changes that much. I mean the money's good, but its not really changing anything.” And then I looked at her when she said that and at first I thought, I felt bad, but then I realized these kids have no idea what most universities are like. They come in and they work with biochemists, environmental engineers, chemists, soil scientists, all these doors on campus are open to them and they have no idea that's not the way it usually is and I thought that was a success comment. A comment documenting success. If a fish doesn't see the water it's in.

In contrast to this PI's conjectures that students in the program were unaware or otherwise did not appreciate what she considered the exceptional opportunities that the IGERT had created, students did in fact reveal themselves as not only aware but also very appreciative of the quality and the value of community as it is being built in this program (like many others) through different mechanisms of participation and inclusion.

Student 1: I'd say our program does a really good job of coordinating functions that we can be at, from semi-monthly luncheons to doing little trips.

Student 2: Requests for participation to help other people via class or some outing or something....Often they'll make requests like they want to go to breakfast to discuss something or

if the students are going off to sample some site, they'll often make requests for someone to drive or someone to go along and help. Those are the kind of things that, we're actively involved in helping keep the...program something that's inclusive to people, working, and functioning.

For many students, however, the real pay-off and measure of a well-functioning community is not in the amount of network or productive collaboration enabled—though these were appreciated. Rather, many students focus on the benefit of the environment's supportiveness:

Student 2: That's one of the strengths that I see in the faculty // that I admire in the...program. That those who are not afraid, because in interdisciplinary science you have to be able to fall on your face when you talk about something. And those that are not afraid to do so, they have gained my respect.

Student 1: And I think on the student level, we have an e-mail list that goes out to everyone, and every once in a while a stupid question comes through [with the introduction], "I know someone on this list can answer this." ... And it's nice to know, just on general science questions, ... like "how do you convert from atmospheres to molar?" I'm sure I could figure it out, but you guys [the other students] know how to do it.

What these students are pointing out is that their IGERT program has built a social scene that fosters enough of a "sense of trust" that they can feel comfortable asking the "stupid questions." For these students, trust is a kind of precondition for cross-disciplinary interaction which often requires one to step out of their areas of expertise and thereby reveal what they do not know. The issue for these students was not that everyone is always "nice" or that work is "not held to high standards," but that people acknowledge and appreciate that no one can know everything and that gaps in knowledge should be filled not criticized. Thus while being "outgoing," "having good interpersonal skills," and being "willing to talk to anyone" are often highlighted in the literature and in our interviews as important personality traits for success in interdisciplinary work, these individual traits may become less significant in interdisciplinary programs like the IGERT where the communal elements are strong.

Building a robust community is no simple matter, however, and respondents discussed a number of key elements that might go into such an effort. Many emphasized the importance of a shared space and resources for IGERT students to use. Others pointed to regularly organized events that combine intellectual and social interactions. And still others emphasized the importance of letting the students organize and administer activities like a program's seminar series or colloquium, explaining this type of role promoted student sense of ownership and investment while also serving as valuable professionalization experiences. Importantly, none of these activities are seen as only influencing students, but also helping to foster cross-disciplinary exchange and social integration among faculty members as well. As one PI explained:

But maybe at a more fundamental level, [the IGERT] has introduced me to faculty on campus who have given me tools and opportunities for collaboration that I would not have had otherwise. Just the mere mundane task of managing the program, running the program means I meet on a monthly basis with scientists in different departments.

A faculty member at a different program also mentioned that the IGERT has fostered new faculty interactions, highlighting the key role that students play in developing and maintaining these relations.

Mostly because, you know if I sat down with you about having an interdisciplinary project between us, it won't happen until we have a student that's going to work between us that's going to make that happen. So basically that's what the graduate students are doing.

What these quotes seem to be demonstrating is that IGERT programs enable interactions and collaborations by giving faculty a platform to develop relationships that are difficult to imagine and implement without mutual commitment to and responsibility for a formalized group, its members, and its activities. In short, the power of IGERT seems to rest less in their ability to actually form new intellectual territories whole cloth and more in their capacity to give necessary form to new intellectual territories underway.

This brings us to another aspect of trust, to return to an idea introduced earlier, and the importance that interviewees assigned to the role of faculty members in modeling good collaborations and good community to the students. For example, in the quotation above, the student conveyed having additional respect for faculty members willing to put themselves out in public and risk “falling on their faces,” thus suggesting faculty can play strong roles in community building by showing their fallibility. Another student noted they can do the same by simply demonstrating their accessibility:

I think at first it was nice to have that list of associated faculty; you had a reason to call them. On the other hand, I'd say that after my first two experiences of cold calling people on the [program] faculty, it's just increased my confidence that I can call anyone anywhere and say, “I have the problem. I think you have the solution. Can we talk about it?”

In this statement we see that in addition to the main benefit of having a previously unknown faculty member providing this student with help on a problem, the experience of contacting them successfully had the additional benefit building the student's capacities to make future connections. Thus, in a fully developed IGERT community, students and faculty are learning how to “be resources in their community” at the same time they are learning to “find resources in any community.”

(4) Problems with Community

Though many IGERTs have had dramatic successes in the production of strong communities and cross-disciplinary interactions, there have been problems as well. For example, according to our interview data (as well as our survey data³), PIs frequently express a desire that faculty members would be more committed to the IGERT program. Usually this meant that faculty do not participate in additional community-building activities such as colloquia as much as PIs would like. However, sometimes PIs also noted that faculty seem not to encourage or even allow their students to collaborate across disciplinary lines.

One of the things that happens quite often, not quite often, but does happen, is we do have a few faculty whose students just don't work with other people no matter how hard we try. Or they'll work with maybe one other group and we just can't expand that. You can try as much as you want to, but you just can't expand it.

One PI summed up the faculty participation situation in his IGERT by stating the following:

My biggest disappointment is faculty participation. We have this weekly IGERT colloquium that all the students are required to attend, and probably two thirds of them are there. And most of the time I'm the only faculty member in the audience, or one or two others... So for whatever reason, most of the faculty have not written it into their calendar that every Friday at one they go to the IGERT colloquium. I've never really tried to confront people on that. But they're all really busy, and they're all really good at serving on the committees, so they're advising the students, they're happy to work one on one with a student from another department in the IGERT who comes to them and says can I work with you. I don't think there

³ See First Interim Report to IGERT Program Directors <https://i3.ssrc.org/extranet/pages/reports.aspx>.

have been problems with that. So they're sort of committed in principle. But they don't--and when we have the steering committee meetings to decide about funding decisions and things, most of them attend. And when I send out emails to get people to vote on things they respond. And when I ask for stuff for an annual report or something, I get a lot of material. But nobody else has taken ownership, I guess, on the faculty.

This PI expresses the complexity of the participation situation. Faculty members are very busy, and IGERT activities often represent “extra-curricular events” for already packed schedules. The PI acknowledges that faculty do a lot to keep the program running, but he wishes they would go a bit further—not just meeting the requirements, but taking on “ownership” and an additional degree of responsibility.

Other commonly cited barriers to community building, interaction, and/or cross disciplinary exchange seem to be connected less to individual attributes and more to structural realities. For example, some programs trying to integrate departments spread widely on large campuses have difficulty creating a mutually convenient common space for students where they can spend time and benefit from the serendipitous interactions so essential to community building. In a similar regard, one student complained that activities promoting interactions were not “timed” well in the sequence of a student’s development to be of optimal utility:

I think that if there was another component that I was a little disappointed with, it would perhaps be that the interaction with other students and other domains was early on. And ...I didn't know where I fit into any of the disciplines early on. So I was meeting them, it was nice to hear what they were doing, but we had no basis for saying “here this is how I think we should interact.” I think that there was not much of a mechanism as the program went on to maintain those relationships.So that has been a little disappointing, because now I'm [sic] think I'm starting to be at the point where the discussions and interactions would mean more than before where it was “hey I'm kinda' thinking about doing this.”

For this student, the interdisciplinary interactions and exchanges happened too early in the process to be of much use, and then were not repeated when students, having gained disciplinary expertise, would have known enough to benefit from differing perspectives. The dilemma, of course, is that students have the most time for interdisciplinary interactions at earlier stages in their professional development when they “don't have a disciplinary prejudice or arrogance that they have to work to overcome” as one PI stated, but when they may “have less established knowledge to trade in a research network” as one provost observed.

Another difficulty many IGERTs face when trying to build fully integrated communities is a kind of “inequality and conflict” between departments. In many of the IGERTs we visited, one department (sometimes two) tends to dominate the program. This unequal representation can take place in a few different ways. For example, in terms of program design, the new interdiscipline might be geared toward the concepts, tools, or problems of one discipline more than others. Thus, the program might be more advantageous for the students or faculty in one department as compared to the others. In addition, enrollments might be unequal with one department providing a greater number of students. In many programs, student recruitment can be a contentious event that draws out simmering conflicts between departments, especially when there are significant departmental differences in ranking (thus ability to attract high quality students), student and faculty funding (thus the ability to put together funding packages), and student requirements (thus the flexibility for incoming students to take extra IGERT classes). In addition, conflicts sometimes take place because of differences between departments and disciplines in their degree of cultural “openness” to interdisciplinarity. The upshot of this is that it is not uncommon to find programs where some students feel supported by their departments,

while others find their departments indifferent or even hostile to interdisciplinary work. The latter scenario was best expressed by one student.

You know, when I go back to my department, I feel like I'm just really out of place, I mean, that, that, that's how I'm going to get my degree, but I just feel really out of place because what I do and where I go and how I interact, 'cause I don't really interact, is so non-traditional, and some people might think that's a good thing, I, I tend to think that it's, kind of alienating and // almost having to... prove my point that I'm not just wasting my time, like I'm not just goofing off.

Though such reception on the parts of departments can be difficult for students who have to face it, one could imagine how it might also be used to strengthen the IGERT community by pushing students closer to its core where they in fact feel more at home. As another student facing an unreceptive department related, "I really, really don't fit into my home department at all....So I spend a lot of my time here [in another IGERT department]." Though these and other statements point to some of the dilemmas they face, at this point in our research it is too early to identify the relative personal and professional risks and benefits students face as members of departments by participating in IGERT programs.

Sometimes the strong relationships and interactions of IGERT communities can themselves have this "double edged" character, presenting problems and opportunities simultaneously. For example one student complained that people were so accustomed to asking her questions, that she had difficulty getting her own work done:

And I think it's funny being sort of in a department that houses a lot of possible tools to answer those questions. I honestly have spent some time over in [name's] lab with the door closed because I didn't want people to see I was there. There's been times when I haven't been able to get my work done because so many people will be like, "Hey I've been thinking of doing such and such. How would I do that?" And "Can I borrow your clipboard?" And you know, cause they don't know how to work with DNA.

Though she initially resented these interruptions as a drain on her time and knowledge, she then reconsidered them as an opportunity:

... at first I was sort of irritated, but now it's kind of fun because I realized these are potential collaborators. If I have something that they don't know how to do, it does make an advantage in certain situations that we can both learn from each other.

Another student worried that the kinds of collaborative interactions on which he relies to gather the data for his research might be harmful to his development as a scientist in the long run:

[I worry that I] can't physically do experiments. That's one thing that I do worry about. That I might be sacrificing expertise. But at the same time, this scientist is running a lab, right? He's—for me personally, I'm looking at this as I'm acquiring project management skills.

In the end, however, he also finds an acceptable rationalization of the potential disadvantage of being too dependent on collaborative relationships—facility in project management may be as valuable as technical laboratory skills. At the same time, his words do highlight a sort of dependency dilemma that many interdisciplinary researchers may face in their careers.

IGERT participants often talk about barriers to community building in terms of language, making the analogy that the interface between two fields can be like the border between two countries where the citizens speak different languages. This image is more than metaphorical in interdisciplinary research because respondents literally mean that it can be difficult for them to communicate with their colleagues from different disciplines. This is reflected in one PI's description of his own entrée into interdisciplinary research:

That's where I really learned about the idea that different disciplines talk about the same thing using different language or about different things using the same language, and about how [to consider] some of the things about overcoming communication barriers.

This speaker implies that there are latent communities of interest “out there” interested in similar issues but unable to communicate. Many other respondents reiterated this point, discussing community building in terms of “translation”—one respondent mentioned literally making up a mini-dictionary at an interdisciplinary meeting. Just as graduate students often turn out to be the link in faculty interactions, they can find themselves being not only the “author” but also the interpreter or translator. One described his experience with his dissertation committee in such a way:

With the chemistry, micrometeorology, and the plant physiology, it's like, I have a committee who, one person speaks English, another speaks French, and the other speaks German. And I have to talk to them all at the same time in the same language, and so, like, it's, it's, ahh....So definitely [I am a] a bridge or a translator in that sense.

Though this bridge position between advisors can be exhilarating for students, it also presents unique challenges to the already difficult task of “committee management,” including making students anxious that their work is not really understood fully by any one of them. The committee is a space where language barriers are felt particularly acutely, but the problem is a much more general concern that most IGERTs and interdisciplines have to confront.

The issue of interdisciplinary language is a point where the idea of community comes together with the cognitive concerns discussed earlier about the cultivation of an interdisciplinary mindset devoted to breadth, complexity, and, mostly, an integrative outlook. One particularly insightful student put the issue this way:

The other thing about a multi-disciplinary program is you're facilitating language between different disciplines. And as soon as you start fragmenting, you kind of reverse the whole trend. You go back to having programmers and biologists. Mathematicians and biologists. What you really want are biologists or scientists who look at biology with a completely different pair of eyes and they're able to communicate with the hardcore [computer science] people and the hardcore mathematics people, but what we're really after here is a change in how we do biology.

What this student highlights here is that language and community are not only about connections and communication, but also are about culture and cognition. Ultimately, if an interdisciplinary research area is going to be that “something more” than cross-disciplinary exchange, it is going to have to produce new ways of looking at and thinking about problems. But, as this student points out, and as our evidence suggests, promoting a new mindset or outlook at an individual level is unlikely to work without a community around it to both sustain it and give it content.

(5) The IGERT Stipends

The topic of IGERT stipends turned up again and again in our conversations. PIs and faculty members view the money somewhat ambivalently, with some serious drawbacks diminishing the unquestionable benefits delivered. On the positive side, the money has allowed PIs to start and grow programs in ways that would have been impossible otherwise, the funding has also freed students to learn and conduct research much more deeply and independently than students funded off typical faculty research grants. However, the restrictions that NSF has put on the allocation and distribution of IGERT funding have caused certain problems in programs.

It perhaps goes without saying that PIs and co-PIs appreciate IGERT money because it allows them to build ambitious programs, often bringing a long-term dream to fruition. Some PIs associate the IGERT money with new program features and benefits that have helped them transform a previous program into a much more robust and creative new form. One PI highlighted how the IGERT has funded equipment purchases which have helped solidify the relationships between students, faculty, departments, and institutions:

Funding an increase in students across the board, building up resources that could be shared; the idea of having equipment and supplies that could be shared across the institutions was very important. And from the beginning we used equipment money to buy things that were--well if the budget was \$200K for equipment and each institution thus got 40, we would make little pockets of money, we'd take 20 from this one and 10 from that one and 5 from that one to buy some shared equipment.

In this description, the money has helped bring together a research community by providing equipment useful to many researchers. More specifically, however, to return to an idea discussed earlier, it also seems to have done this integrative work by giving dispersed researchers a common stake in decision-making and "ownership" of equipment. Another PI discussed his hopes that the IGERT would help his department move up the national rankings:

We are always competing with the top 10 departments, we were ranked 11th geography department at [university] in the NRB rankings 6 or 8 years ago. We were the highest ranked department in the university in terms of absolute ranking. So we have lost IGERTs only to the top ten departments ahead of us. When we make an IGERT offer they either come here or they go to one of the top 10. Those are top 10 for a reason, they have more to offer overall than we did as of last time. We're hoping that thanks in part to IGERT we'll move into the top 10 next time evaluations are done. But there are some strong departments who were just behind us last time. So we might leapfrog three but still be 11.... I think it has allowed us to attract a larger number of more highly qualified, maybe even smarter, people into the program. They are some of the intellectual and social leaders of the geography student body here. So it's really helped us be competitive for some of the best applicants in the country. And that's just the money.

By helping recruit the best students in the country, this PI sees IGERT money as giving the program a competitive edge against its more highly ranked competitors.

Students, of course, are the biggest beneficiaries of IGERT funding, and the most significant benefit comes in terms of their freedom to pursue research and training without having to meet the demands faculty members paying them from grants. As one student remarked:

One of the best things about this is that I am financially independent from my department and my advisor. That's a very good thing....My interests are not perfectly matching with either of the faculty that I'm working with. So, being independent I feel basically more safe, like someone isn't pushing me to do something that is not in my interests from either side of it.

Interestingly, however, this student was a relatively rare case in describing the impact of IGERT funding in this way. This benefit seems to be another one of those "taken-for-granted opportunities" introduced above by IGERT students because almost none mentioned it in the interview and were only likely to talk about funding as an afterthought if at all. More generally, they tended to mention particular research or travel opportunities rather than more general impacts on their research or personal lives.

In contrast, faculty tended to recognize much more readily the impact of IGERT funding, in terms of granting student freedom and also thereby generating exploratory research.

Interviewer: So [program] has actually given you the freedom to give them the freedom

Respondent: I think that's exactly right. I mean, there's no question that that's true. And that's totally independent of it being interdisciplinary.

This speaker also worried about that the impending end of his program's funding would fundamentally alter his teaching philosophy and the student/faculty relationships he has established.

And so those five students are certainly working on things that are not my babies at all; not even close. Now [program] is coming to an end, and we don't know. It might get renewed. But it's causing me to rethink that philosophy [of letting students choose their own projects]...and I'm sort of counting how many students can I take on and what are they going to work on?

One PI noted that IGERT funding gave students not only independence from faculty members, but also enabled and encouraged high-risk, exploratory research:

The biggest difference is the fact that they can work with other groups and they actually, their money is not tied to a specific project, so they can do exploratory research--truly exploratory. It's risky and it may not pay off, but the advisor doesn't really care because you're willing to risk it. With a grant I can't do that. That student has to be doing what they're supposed to be doing. With the IGERT students they can see a problem and say, "Hey, that's kind of an interesting problem; let's try to do that."

The speaker went on to describe how fruitful this exploratory research has been and that at least fourteen patents have resulted from it.

Even though it is true that IGERT-funded release time and research expenses for faculty are limited, the money has helped some faculty members keep their labs going. For example, one faculty member at the beginning of his career found that IGERT funding was essential to establishing his lab:

[Students] have access to funding, are promised four years in this case, and frankly without that kind of support I'm not sure how I would have got my lab going, which is a bit selfish but true. Especially because I did have a difficult time getting my first sort of a standard NSF grant. Very difficult time. I'm not sure how other people do it to be honest, without access to those kinds of [resources].

This respondent continued:

I think that because of [IGERT] funding I may have been a little gutsier than I needed to be. That's possible. That's not to say that's good or bad; I'm just saying that maybe if I had been starved for money I might have focused on much smaller standard stuff that could be funded.

Thus, the IGERT money has actively albeit indirectly encouraged innovative research amongst the faculty as well, if having the security of IGERT funded students in the lab enables researchers to pursue more ambitious research agendas than they would had they needed to support a number of students with their own grants.

With the good sometimes comes the bad. IGERT money, however, also generates a number of complaints, especially from PIs and those administering programs. Paramount among these is the complaint about the NSF-mandated \$30,000 annual per student stipend rate. The main concern voiced by many PIs and faculty is the inequality these stipends produce between students and lab-mates. One faculty member said,

I think one of the things that I find both interesting and horrifying at the same time is the discrepancy in stipends because I have a student who is currently getting the standard IGERT stipend, which is thirty grand or something like that, and he is sitting there working essentially

for—because he’s learning—one of my more senior graduate students who’s about to get his degree who is getting paid eighteen out of a different set of grants. And this does not make for a happy company. Particularly when—the student that I currently am sort of operating with as if he were a post-doc is getting paid half what somebody that he is actually mentoring is getting.

However, beyond voicing concern about this inequality, those PIs and faculty members that discussed it did not indicate specific problems that inequality produced.

Compared to PIs and faculty, however, IGERT students rarely mentioned funding inequality as a source of IGERT/non-IGERT tensions. In this quote, a student barely hints that IGERT funding produces tensions between them and non-IGERT students:

There are a couple [of non-IGERT students] that I have talked to are absolutely astounded at the opportunities that I have because of this program. That I have travel money and research money at my disposal. I’m able to do these sorts of things. The idea of doing an outreach thing for my teaching requirement was well-accepted and funded, and so I don’t know about jealousy per se, but I think it sort of blows their minds when they find out what our structure is. And a couple people have said, “Oh, but you have to take extra classes. Like, wasn’t that wasting your time?”.... And it’s just their attitudes. I mean, our department thinks you need to be in lab all the time and never look up.

What is interesting is that the student attributes the tensions not to the inequality in stipend amounts between IGERT and non-IGERT students, and she dismisses the idea that other opportunities supported by IGERT funds are really the key difficulty. Rather she attributes the tension to the different structure of requirements and opportunities IGERT students have—according to her it was the ability to do outreach to fulfill a teaching requirement more than funding per se that was among the most surprising for non-IGERT students to accept. However, as said previously, the issue of stipends came up infrequently in student interviews and this is one of the few explicit mentions we have of such tensions in our student interview data. It is possible, though we cannot yet fully support the claim with data, that tensions reported by faculty and PIs between IGERT and non-IGERT students concern not funding inequality but other opportunities and distinctions that IGERTs enable.

Apart from inequality, interviewees reported a number of other frustrations with the IGERT funding arrangement. One problem that students, faculty, and PIs alike mentioned is that some students who benefit from IGERT funding treat it as just a funding source and do not invest in the program, either by participating in its particular activities or engaging in cross-disciplinary interaction. As one PI described:

One of the things that happens quite often—not quite often, but does happen—is we do have a few faculty whose, their students just don’t work with other people no matter how hard we try....When I started out, of course, you always make some mistakes. After a while though, I started to realize who was really serious in terms of advising and allowing their people to work with other people and I tried to steer students toward certain groups.

Respondents were not surprised that this took place, as the same PI explained: “[faculty] want to expand their research efforts, but they don’t want to give up a lot. They want to keep their economy and make sure that they’re in control.”⁴

PIs often expressed the desire that NSF would allow IGERTs some flexibility to adjust the student stipends from the established NSF rate. They understood that there are many reasons

⁴ Interestingly, he made this claim about “scientists and engineers” but said that medical researchers rarely exhibit this problem because they “want new techniques” and are eager for cross-disciplinary exchange to acquire them.

why the stipend rate should be set as it is, but they often described unintended problems which they felt might be avoided by the chance to disperse them differently. According to one PI, the stipend rate acts as a barrier to interdisciplinary engagement since his IGERT tries to integrate departments with unequal funding bases. His program is structured so that the IGERT will pay for two years of funding provided the department can pay for two other years (even at non-IGERT rates). The aim was to stretch IGERT money further, involve more students, and hopefully to institutionalize the program so it could persist when NSF money ended. This posed no problem for well-funded departments and faculty with large grants. But students hoping to enter the IGERT from poorer departments who do not fund many students were unable to join the program while students from richer departments (sometimes with fewer qualifications) were able to join. The PI complained that the firm stipend rate, intended in part to eliminate program inequalities,⁵ was here exacerbating them through the back door—“it’s a rich get richer kind of thing”—because he was unable to adjust stipend rates to subsidize students from departments unable or unwilling to pay. No other PIs, perhaps not attempting such difficult bureaucratic moves or not building programs overlapping such unequal departments, complained about this issue. But they did worry about the funding rules in other ways—particularly wishing they could have built more release time into the program since their universities did not extend this perk or give them credit or recognition for IGERT funding because of its teaching, not research, focus and low overhead rate.

Overall, then, while IGERT funding was seen as a great opportunity to build programs and communities and to provide students a uniquely freedom-filled educational experience, the high stipend rates and rules governing funding caused some problems a few of which contravened NSF’s intention to stimulate interdisciplinarity.

(6) Differences in Faculty and Student Perspectives

For the most part students and faculty in IGERTs seem to be happy with each other and work well together. But it is worth pointing out a few latent but persistent conflicts we heard about in our interviews. The first concerns student perceptions of the advising relationship. As noted above where the student compared his committee to speakers of three languages, students face a challenge working with advisors from multiple fields. Students frequently feel like they were not given enough guidance by their faculty members. At the extreme end of this, students have reported that faculty advisers have given conflicting and uncoordinated guidance, leaving the students to figure out what they are supposed to be learning on their own. One student went as far to say that he wished that faculty members had more of a plan for students, that: they were “connected at the higher level, like so they participate in the co-development of the student. Not over here and over here and then it all gets sorted out by the student, but there’s a bigger plan.” Other students felt that the particular structure of multiple-department co-advising meant that they had to work hard to manage their advisers.

So it’s a tricky game there. I basically have to coordinate through them. Each of them wants his decision to be more important than the other there. “I’ll say when you’re done,” [says one advisor,] and the other says “No, I’ll say when you’re done.” That’s the game. From the perspective of the department, my departmental advisor is more important.

⁵ Though none suggested this directly, in comparing IGERT rates to other stipend rates in their universities, PIs implied that inequalities could have been overcome and flexibility increased by setting stipends at or marginally above the best going rate locally.

Moreover, quite frequently students felt that the model whereby the faculty members' interactions are mediated by the student was insufficient.

I don't think the faculty talk enough, interact enough. And I think that was part of it. They're supposed to // they say the ideal goal was to, "okay you have this grad student and then all the interactions go through the grad student." But, I think that's a misnomer, I don't think that's true. [laughs] 'cause faculty are very much independent and have their own research agenda.

In some cases, student/faculty conflicts are even more apparent, as when students complained that faculty members made them work too much on research projects not related to their dissertation research. This is a common problem in graduate science education and, as discussed above, by freeing students from faculty grant support the IGERT fellowships clearly mitigate it in some instances. However, it is possible—though we have no direct evidence—that the fact that IGERT students are often less engaged in departments might mean that they may not enjoy the kinds of protections and oversight of research relationships that departments often offer.

Students and faculty also have different senses and expectations of the students' chances on the job market. One student described the difficulty he experienced going on the job market with an interdisciplinary degree:

... the job search and moving on has been a very challenging and disappointing part [of being in the IGERT].... I think that one thing I found in interviewing going out from this program is that—I think the objectives of this program were to break down some of the discipline defined molds between different faculty and different students. And I think it accomplished that, but the question is, where do you go after that?... So I think I've been able to apply to a lot of positions, and I think I've gotten my foot in the door. But sitting down and talking to them, they have three candidates and they're looking for [field]. Someone's that specifically that, well the match hurts me, or has hurt me with specifically getting my foot in the door.

Other students expressed their fears of encountering an experience just like this themselves, pointing specifically to the capacity—or the lack thereof—of faculty, who are themselves employed in a particular discipline with its own networks, to tap networks beyond their field to help students on the market.

I think that's also my problem, that [faculty name], she's well known. But as far as having that oomph. Of like "Yeah, people that come out of her lab really know their stuff." I don't know if [name] understands my projects. I mean, I kind of feel like I'm on the—I know [other faculty name will] help me, but it's sort of tough.... And I keep thinking, like who's my third letter? It's nice to have more options.

Faculty members, in contrast, do not feel that students will have problems with employment. In our interviews across many different IGERTs we heard faculty members repeat the label of their programs as "discipline plus" when we asked them about students' job prospects. Most of them told us that the design of the program would ensure that students were not disadvantaged on the market and that instead involvement in the IGERT would, "give them is something on their CV or resume looks different and distinguishes them." However they seemed relatively unaware of students' other concerns.

Not surprisingly, faculty complaints of students are much more limited and predictable than student complaints about faculty. Faculty complain occasionally about student quality; we heard concerns that students are not proficient enough in mathematics voiced in multiple programs. More striking, however, were complaints, once again, about commitment. Some were about students who treated IGERT funding as just a source of support and did not engage the program's ideals. Sometimes faculty were discouraged that students seemed unwilling to take on

the extra work that IGERT programs represent. Even when they acknowledged that students have many demands on their time and cannot always meet every expectation, there was often a hint that students are not trying hard enough or simply lacked dedication. One faculty member made this view clearer than most:

We intended at first that people would become almost as accomplished in the field that had no experience with as in their main work. And it really wasn't that intelligent an expectation. I don't think anyone has really accomplished that. Even the person that first comes to our mind as sort of our poster child is not particularly interdisciplinary....And the things that have limited us, I think, are attitudes. It's just the intellectual orientation of students and mentors. Where they just aren't as gung-ho about being interdisciplinary as we are.

The following and final quote illustrates the immense pressures students in IGERT programs find themselves under. It should also leave little doubt that, whether or not they are meeting the standards for interdisciplinarity that programs set out for them, they are eager to have their minds and perspectives remade and put themselves through extraordinary efforts to do so.

I, I feel that my department is very much, inflexible in terms of, you know, they think that a student should come in, they should get all their required courses done in the first three semesters, take Comps I right after the third semester, that's the written form. And, and I have already, you know, have missed that, that opportunity, because, I wasn't able to take the, the full load this past year, partly because of my mathematical deficiencies and partially because of my research obligations. And, so, I don't even know what they're going to have to say about // they're aware that I will not be taking Comps I and the right scheduled time, but, I mean // You know, and my advisor, he's, he's much more research oriented, you know, he, he tends to put the academic stuff under the table and say, "Well, you know, you're a doctoral student, you're, you know, research is what you really do, it's not about classes." Umm, unfortunately the people in my department don't feel that way. I mean, they feel that it's about research, but only after your first three semesters are over. So, I'm not sure it's been a fun ride, you know, there've been days where I've just been emotionally drained, ahh, mentally exhausted. I worked for, you know, I worked // I put in so many 15 hour days this past year, I // it was unbelievable. And then there's days where I just, I feel like I'm doing real meaningful work, and umm, I feel like I'm having this accelerated mental revolution going on, it's changing // it's changing the way I'm thinking about things, becoming more meticulous, more mathematically oriented. I'm learning stuff at [program], I'm learning stuff at, you know, about physics and dynamics, umm... Wow, it makes me tired just thinking about it all!

This student is not enrolled in the IGERT program just for the funding or to take an "easy road" by dodging the rigors of disciplinary training—a motive that critics of interdisciplinary training sometimes attribute to interdisciplinary students. According to her account, sticking close to the department's expectations and fulfilling its requirements would have been the easier path. Instead she is pushing herself to become a rigorous researcher able to pass her department's comprehensive exams while at the same time altering the way she thinks, undergoing an "accelerated mental revolution."

Thus, we arrive back at the themes discussed earliest in this report—this student is motivated in large part to develop an *interdisciplinary mindset* and is willing to go through formidable challenges while struggling to balance contradictory demands to do so. Faculty who have passed successfully through the training process often many years earlier perhaps forget how difficult and exhausting even regular graduate education can be, let alone interdisciplinary training.