High Educ (2011) 62:741–755
DOI 10.1007/s10734-011-9415-1

Student socialization in interdisciplinary doctoral education

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Published online: 6 February 2011

Abstract Interdisciplinary approaches are often seen as necessary for attacking the most critical challenges facing the world today, and doctoral students and their training programs are recognized as central to increasing interdisciplinary research capacity. However, the traditional culture and organization of higher education are ill-equipped to facilitate interdisciplinary work. This study employs a lens of socialization to study the process through which students learn the norms, values, and culture of both traditional disciplines and integrated knowledge production. It concludes that many of the processes of socialization are similar, but that special attention should be paid to overcoming organizational barriers to interdisciplinarity related to policies, space, engagement with future employers, and open discussion of the politics of interdisciplinarity.

Keywords Interdisciplinary · Doctoral education · Graduate education · Socialization

Introduction

Interdisciplinary approaches are often seen as necessary for attacking the most critical technological and socio-technological challenges facing the world today (Brainard 2002; National Institutes of Health 2006; National Science Foundation 2006). As the next generation of researchers (Walker et al. 2008), doctoral students and their training programs are recognized as central to increasing interdisciplinary research capacity. In recent years several groups have independently concluded that interdisciplinary training is an important new direction for graduate education (Golde and Walker 2006; Lamancusa et al. 1995; The Woodrow Wilson National Fellowship Foundation 2005). While the value of interdisciplinary graduate education is increasingly being recognized, considerable barriers to

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cross-disciplinary efforts persist (Amey and Brown 2004; Committee on Facilitating Interdisciplinary Research 2005).

The higher education institutions in which graduate students are trained are ill-equipped to facilitate interdisciplinary research, teaching, and other aspects of interdisciplinary graduate training. The challenge is two-pronged. Not only do professors and students need to work laterally across an organization that is typically very hierarchical in nature, often finding that deans and department heads are unwilling to commit their own resources to benefit other divisions, but this disciplinary department structure is a schema that extends well beyond any individual institution to discourse communities reinforced by professional societies, journals, and the like. These disciplinary communities have been described as territorial "tribes" with their own characteristic cultures (Becher and Trowler 2001; Reich and Reich 2006), and a number of studies have highlighted associated differences (e.g., Anderson 1996; Donald 2002; Turner et al. 2002). Austin summarizes:

> Each discipline uniquely defines and legitimates research questions, research methods, the relationship between teaching and research, and work relationships between scholars. These disciplinary variations can make significant differences in the lives of faculty members. For example, a faculty member in English is likely to conduct research alone, while a professor of chemistry is more likely to have a team of colleagues and graduate students with whom he or she collaborates. Humanities scholars tend to value books and monographs as products of intellectual work, whereas natural and physical scientists, and many social scientists, tend to favor refereed articles. (2002, p. 97)

This conception of disciplinary culture is useful in describing socialization of newcomers such as graduate students and new professors, including understanding why some succeed in a given set of circumstances while others fail (Gardner 2008; Tierney 1997). Tierney summarizes, "culture is the sum of activities in the organization, and socialization is the process through which individuals acquire and incorporate an understanding of those activities" (1997, p. 4). Socialization is a "common and useful framework" for understanding graduate students' experiences in particular (Golde 1998, p. 56; Weidman et al. 2001).

Many scholars identify the department and/or discipline as the principal site of graduate student socialization (Gardner 2007; Golde 1998), due to strong control over admissions, funding, and degree requirements influenced by disciplinary norms and practices (Golde 2005). However, in focusing on socialization to departments and disciplines, Gardner found that socialization occurs also to the cultures of "graduate education, its values, and tenets across institutions and disciplines" and "institutional culture, which includes general norms and procedures governing the day-to-day working of the graduate enterprise" (2007, p. 737). In other words, while typical graduate students are being socialized to a particular discipline and department, they are also socialized to a culture of higher education as being *organized by disciplines*. The result is feelings of isolation by students in programs or projects that span traditional disciplines (Tress et al. 2009) due to conflict with "the long-accepted structure of the academy" (Holley 2009, p. 242).

This analysis is not concerned with identifying the specific differences between disciplinary cultures, but rather in scrutinizing the *culture of disciplinarity* that dominates most higher education institutions and stands as a barrier to coexistence of a fully legitimate *culture of interdisciplinarity*. It is guided by the research question: How, if at all, are the values, attitudes, norms, knowledge, and skills to which graduate students are socialized different for interdisciplinary, as opposed to traditional disciplinary, graduate programs?

This interview study of 43 students, professors and administrators from four different interdisciplinary programs at two large public universities samples broadly across domains to understand socialization in interdisciplinary graduate programs within discipline-oriented institutions.

Theoretical framework: socialization in interdisciplinary doctoral programs

Socialization is a broader concept which has been extensively applied and conceptualized within graduate education to understand student development and attrition (Gardner 2008; Golde 1998; Lovitts 2001; Weidman et al. 2001). Weidman quoted Brim to define socialization generally as "the process by which persons acquire the knowledge, skills, and dispositions that make them more or less effective members of their society" (1989, p. 293). Specific to graduate education, socialization is "the processes through which individuals gain the knowledge, skills, and values necessary for successful entry into a professional career requiring an advanced level of specialized knowledge and skills" (Weidman et al. 2001, p. iii). It encompasses the entire developmental process of moving from a novice to a full-fledged member of a professional community. Thus, socialization of doctoral students occurs simultaneously at multiple levels (Golde 1998), as graduate students are socialized to both current (student) and future (professional) roles (Austin 2002).

Weidman et al. (2001) identified four stages of graduate student socialization. During the anticipatory stage (i.e., recruitment), the individual forms generalized and stereotypical role expectations, primarily through mass media and observation of role models. In the formal stage, graduate students receive more structured instruction regarding norms and expectations, but these remain idealized. "Communication becomes informative through learning course material, regulative through embracing normative expectations, and integrative through faculty and student interaction" (Weidman et al. 2001, p. 13). In the informal stage, students learn more subtle and informal expectations through immersion in the culture, taking cues from professors and fellow students. During the final personal stage, students form a professional identity that aligns with the chosen profession and reconciles previous role conflicts. This stage is also characterized by deeper engagement with research and professional activities, such as involvement in publishing, internships and conference attendance. Throughout the stages, interaction with students, professors, and (less frequently) professionals is central to learning the culture.

Summarizing prior work in socialization, Tierney (1997) defines culture as "the sum of activities symbolic and instrumental that exist in the organization and create shared meaning" (p. 3) and concludes, "An organization's culture, then, teaches people how to behave, what to hope for, and what it means to succeed or fail" (p. 5). Higher education is characterized by disciplinary cultures (Anderson 1996; Becher and Trowler 2001; Donald 2002; Reich and Reich 2006; Turner et al. 2002), thus the disciplinary department is the primary culture to which graduate students in traditional programs are socialized. Indeed, many scholars identify the department and/or discipline as the principal site of graduate student socialization. Golde explains that graduate students are socialized to "the community of an academic department in a particular discipline" (1998, p. 56). Gardner argues that "the discipline is the home and central reference point to the graduate student" (2007, p. 724). Both cite a number of others (e.g., Berelson 1960; Bowen and Rudenstine 1992; Gumport 1993a, b; Heiss 1970; Nerad and Miller 1996) in establishing that "the department…is the locus of control for doctoral education" (Golde 2005, p. 671). Golde continues:

> The department largely determines the policies that affect student life. Admissions, financial support, the requirements for degree completion, and the curriculum are all determined and controlled by the department or program…Simultaneously, departmental practices and cultural assumptions about doctoral education are shaped by disciplinary norms and practices (including the job market in the discipline) and by the nature of research and scholarship in the discipline. (2005, p. 671)

Students in traditional discipline-based programs have the benefit of an established disciplinary culture, or at least consensus regarding "what counts as knowledge" (Tierney 2008, p. 52). The strong influence of department and discipline has been used in countless graduate education studies to motivate sampling across broad disciplinary categorizations (e.g., Biglan 1973) and highlight similarities and differences. However, in focusing on socialization to departments and disciplines, Gardner (2007) found that socialization is also to the cultures of graduate education and institutional culture beyond the department. In other words, while typical graduate students are being socialized to a particular discipline and department, they are also socialized to higher education as being organized by disciplines. This strong organizational structure lies at the heart of many of the challenges to interdisciplinary research and graduate training.

The numerous challenges to interdisciplinarity in higher education settings are well documented in the literature. While there are clear intellectual challenges such as resolving inconsistencies and incompatibilities among disciplinary lexica and perspectives (Boix Mansilla and Dawes Duraisingh 2007; Bromme 2000; Gooch 2005; Klein 1990; Lattuca 2001; Salter and Hearn 1996), the exact nature of these challenges varies by interdisciplinary domain, in part due to the contributing disciplines (Repko 2008). The focus of this study is less on the intellectual challenges of a specific interdisciplinary domain than on the barriers related to the organizational structure and culture of traditional disciplinary departments that are experienced by a broader cross-section of students, professors and administrators associated with interdisciplinary graduate programs. As Holley states, "The organizational culture of the university is one divided by disciplinary ways of thinking and behaving" (2009, p. 242). Resources, rewards and accountability are directed via a hierarchical organizational structure of departments, schools, and colleges. (Novel organizational structures such as research centers and institutes can direct resources such as research assistantship funding to new interdisciplinary endeavors (Sa 2008); however, departmental alignment remains the norm.) Established disciplines—some more than others—have reached a degree of consensus regarding what constitutes quality work (Pfeffer 1993) that is absent in most interdisciplinary domains. Since so few referees are sufficiently knowledgeable about multiple foundational disciplines and their synergistic integration, interdisciplinary work is far more challenging to evaluate (Committee on Facilitating Interdisciplinary Research 2005; Oberg 2009; Payton and Zoback 2007; Pfirman et al. 2005). Administrative concerns over efficient use of budgeted funds, difficulties evaluating interdisciplinary work, and the additional time it takes to sufficiently integrate perspectives all stand as strong disincentives for junior researchers (particularly untenured professors) to pursue interdisciplinary scholarly work (Pfirman et al. 2005). The U.S. National Science Foundation (NSF) Integrative Graduate Education and Research Traineeship program currently under study also reinforces this privileging of disciplinary contributions. According to the request for proposals, "Students should gain the breadth of skills, strengths, and understanding to work in an interdisciplinary environment while being well grounded with depth of knowledge in a major field" (National Science Foundation 2010, p. 4). The typical model for these programs is for students working toward

PhDs in traditional disciplines to complete additional coursework and other training requirements (e.g., workshops, internships) designed to provide breadth without sacrificing depth (Borrego and Cutler 2010).

Thus, the additional time and career risk arising from organizational barriers to interdisciplinarity prevent researchers from taking the time to develop common ground between differing disciplinary lexica and perspectives by interacting with the very colleagues with whom they can collaborate on interdisciplinary research or learn about alternative perspectives. If professors cannot survive the promotion and tenure process by conducting interdisciplinary research or supervising interdisciplinary theses and dissertations, then they cannot create or sustain the organizational culture required for socialization to an interdisciplinary research career. The result is additional time and frustration for students, supervisors who discourage interdisciplinary thesis projects, and student feelings of isolation that could ultimately lead to attrition (Golde and Gallagher 1999; Graybill et al. 2006; Tress et al. 2009). Nonetheless, a cadre of professors committed to interdisciplinary research has emerged and is working toward training the next generation. This paper describes how they socialize students in their interdisciplinary programs to a new culture of knowledge production within universities whose organizational structure and culture hinder interdisciplinary work.

Methods

Qualitative methodology

This descriptive qualitative study (Patton 2002) is guided by the theoretical framework of graduate student socialization (Gardner 2008; Golde 1998; Lovitts 2001; Weidman et al. 2001) adapted to an interdisciplinary setting. As explained above, socialization describes the processes through which graduate students become competent members of a culture (Weidman 1989). To address the research question, the study design focused on understanding the interdisciplinary culture of their programs and the processes through which students learned the culture. Semistructured interview protocols for students included questions about how their experiences differ from students in traditional programs, their career goals, details of their coursework and research, what made their experience interdisciplinary, and benefits and challenges of their programs. Expanding previous studies which focused specifically on students, this study recognizes the influence of "those who establish organizational norms" (Tierney 1997)—the professors and administrators at the institutional, department, and program levels "participating in the re-creation rather than merely the discovery [or simply the transmission] of a culture" (p. 16). Semistructured interview protocols for professors and administrators included questions about personal experiences becoming involved with interdisciplinary research, the interdisciplinary curriculum, recruitment of students, desired outcomes, creating an interdisciplinary environment for students, and connections to other interdisciplinary efforts on campus.

Setting

This study examines socialization of doctoral students in interdisciplinary graduate education programs at two public U.S. higher education institutions, both recipients of multiple IGERT grants from the NSF. IGERT is the flagship funding program for the NSF's Division of Graduate Education and widely regarded as a premier source of innovation in

interdisciplinary graduate education, particularly across U.S. institutions. The most recent independent evaluation of the program (Carney et al. 2006) surveyed over 1,000 students, 1,000 professors, and nearly 100 department chairs to compare IGERT-affiliated departments to a control group comprising peer departments. Statistically significant differences were reported for interdisciplinary educational and research opportunities including increased opportunities afforded by IGERT for collaborating across departments/disciplines, attending conferences in other disciplines, and publishing in other disciplines. Department chairs and professors at IGERT institutions reported significantly greater support for interdisciplinary research and teaching than the control group. Impacts on promotion and tenure were modest, but 20–35% of administrators responded that IGERT has resulted in changes to interdisciplinary teaching policies at their institutions (Carney et al. 2006). A more recent NSF report (Van Hartesveldt and Giordan 2008) profiles specific policy changes at a smaller number of universities, including coauthored doctoral dissertation chapters.

IGERT grants fund 10–40 graduate students in a specific interdisciplinary area of research over a period of 4 years. In a less formal way than an institute or research center, IGERT grants assist in developing or augmenting a community or network (if not a culture) of graduate students and professors focused in a specific interdisciplinary domain and spanning the university's organizational structure (i.e., departments). Encouraging and maintaining participation in the network is a perpetual challenge to principal investigators (Hrycyshyn 2008), as seminars, workshops, advisory board meetings, and other events are usually scheduled above and beyond departmental events and responsibilities but with fewer visible benefits.

Specific interdisciplinary graduate programs funded by IGERT were initially selected for study due to their broad range of participating disciplines including social sciences, the arts, engineering and computer science; data collection and analysis were later expanded to all programs on the two campuses that were funded by this initiative. Each of the two universities in this study had at least four IGERT awards, but only two programs on each campus were actively funded by NSF at the time of our visits. Due to the availability of current professor and graduate student participants, this study relies heavily on the programs that were currently funded at the time of our site visits. In addition to the principal investigators (PIs), other professors and students from the active programs, we also interviewed at least one investigator from each of the programs no longer funded by IGERT and graduate dean(s) at each of the institutions. To ensure anonymity, the institutions and interdisciplinary programs are referred to by pseudonyms. The disciplinary backgrounds of students and professors from these actively funded programs are summarized in Table 1.

Data collection and analysis

Permission to observe participants from these programs was approved through human subjects (IRB) review at both institutions. Data collection took place during multiple visits to each institution between fall of 2007 and spring of 2009. Access was gained by initial contact with the PI of the IGERT grant, followed by more specific assistance from the program coordinator to recruit students and professors for interviews. Additional participants such as university administrators were contacted directly. As part of this study, 43 interviews lasting 1 h each were conducted with professors, students, support staff, and administrators at both institutions. Two interviewers were present for most of the interviews. Following the interviews, the recordings were transcribed and all identifying

Table 1 Summary of active IGERT sites included in this study

Institution	Pseudonym	IGERT theme	Disciplines (included but not limited to)
Eastern State University	ESU-A	Materials science and engineering	Agriculture, chemical and biological sciences, medicine, engineering and natural resources
Eastern State University	ESU-B	Sustainability: ecology and the environment	Physical sciences, engineering, and social science
Western State University	WSU-A	Computational science and engineering	Social sciences, engineering and computer science, arts (dance, music, theater, film), design, and life sciences
Western State University	WSU-B	Sustainability: ecology and the environment	Social sciences, life sciences, planning and public affairs, and engineering

information was removed from the transcripts prior to analysis. Constant comparative method (Bogdan and Biklen 2003) was employed during data analysis, as well as informing the expansion of data collection to all IGERT interdisciplinary programs at the two institutions. In addition to traditional aspects of socialization, themes which emerged early on included organizational structures and university-level policies. These were integrated into the actual coding process through inductive analysis completed after data collection. All three coauthors participated in conceptualizing the results and data analysis. As an additional credibility check, a draft of this manuscript was shared with all participants before submitting it for peer review (Creswell 2007; Lincoln and Guba 1985).

Findings

Socialization within interdisciplinary doctoral programs

As Lovitts (2001) explains, socialization occurs as students interact with professors and other students in a variety of "intellectual and professional tasks" (p. 42). These interactions are important in that they build relationships between students and professors and provide opportunities for integration. As is the case in many doctoral programs, the students in our study were first academically integrated into their program through the relationship with the dissertation supervisor. For example, when asked how she became involved with WSU-A, one student replied it "was mostly through [my supervisor]." She further explained, "[My supervisor] collaborates with [the WSU-A PI]" and "[he] sent me the IGERT opportunity…I applied for the IGERT not even really realizing that it would entail being involved with [WSU-A]." In this case, the student was not searching for an interdisciplinary doctoral experience, and WSU-A was probably not as well-advertised to her cohort as department opportunities; however, she became aware of and was ultimately invited to become a member of this interdisciplinary intellectual community through her supervisor. A major difference is that this student would not even be aware of the interdisciplinary community if her supervisor had not alerted her; in contrast, disciplinary communities are so established as to be common knowledge.

In addition to funding opportunities, the graduate student-supervisor relationship was an important means for students to integrate academically with other scholars, particularly those beyond their home department—one aspect of socialization that is particularly important in interdisciplinary programs. These students have the opportunity to be

integrated into "*dual* intellectual communities, disciplinary and interdisciplinary" (Graybill et al. 2006, p. 760). When asked to describe the benefits of ESU-A, a fourth year student explained,

> [ESU-A] just gives you a vastly different perspective, because again, you're meeting other graduate students, other faculty and forming relationships with them. You're talking about science; you're asking questions, what are you doing? why are you doing it?… But to think that I would have these prominent people working with me…I would have never dreamed that possible and would have not had the thought or courage to ask them if they would work with me.

Several students from both institutions echoed the sentiment that the relationships forged through their interdisciplinary graduate programs provided greater contact with preeminent scholars from various fields whom they might not have met otherwise.

As noted above, supervisors provide important initial connections for their students to enter interdisciplinary professional and institutional relationships. Our data, however, indicate that in the case of this funding mechanism, during the proposal-writing stage, many primary investigators did not take into account the importance of building a stable culture in which to socialize students when selecting potential collaborators for interdisciplinary graduate programs. The ESU-A PI explained,

> I think the selection of faculty is key [to a successful interdisciplinary doctoral program]. You have to find faculty who are exceptionally passionate. Most faculty are passionate, but you need faculty who are very passionate in interdisciplinary values…who think that it is the way…to solve research problems and educate students.

This is significant in that a lack of care in selecting this most basic level of colleagues can jeopardize a project's integrity or produce unintended consequences. For example, some of the students interviewed were involved in their program primarily because they were offered a financial package that they could not refuse (IGERT stipends are typically higher than what students would otherwise be paid.). This, accompanied with a lack of personal buy-in facilitated by socialization, can be counterproductive to the goals of the interdisciplinary program.

The following is an excerpt from an interview with a first year student in ESU-A, which demonstrates a low level of interest in the interdisciplinary program:

Student:	It's more of a bureaucracy—the whole IGERT… thing…professors come up and say, "You need to do something to get funded in our department so we'll do this, and change our research and overall goals to get it."
Interviewer:	Does that bother you?
Student:	I don't care because it benefits me. Like I said, I get plenty of benefits out of it…I don't really care. Let's be honest, I'm selfish and still 22 years old, I'm going to be selfish for a few more years. I think I have to worry about me at this point. So it doesn't really matter

In this extreme case, it appears that this student has not been socialized to understand or appreciate the value of interdisciplinarity. As such, this student is unlikely to become fully integrated to the program, choosing instead to engage only in activities viewed favorably by his home department. This student's perspective restricts access to the educational benefits of the interdisciplinary program, and in certain circumstances, could undermine the efforts of others to build interdisciplinary communities.

Several of the professors interviewed spoke of the importance of developing their own community for students within the interdisciplinary programs. The WSU-A PI explained:

> Students feel like they have to have a home…the sense of having a home, both intellectually and actually physically [is very important for students]…We work very hard at [WSU-A] to actually make people create communities here… People want a sense of belonging…so that was definitely a [big question], what do you give people to replace their disciplinary identity? You have to work on it…people need a sense of belonging and we all knew that.

One way WSU-B has created a sense of community has been to provide shared student workspace. The student-designed space includes amenities intended to encourage formal and informal interactions among students. The space provides access to office equipment such as computers and printers as well as moveable tables and chairs to accommodate small meetings or discussion groups. One WSU-B student explained that the space also includes a "lounge area with couches and chairs" that encourages informal interactions among students. In describing how the space has been of personal benefit, another student said that it provided a place for discussions between students regarding "what we're working on at the moment or in general other things that we've talked about [in class]." For this student these relationships with colleagues from disparate academic backgrounds made it "easier" in and out of class to "ask [discipline-specific] questions" that did not fit into her "current knowledge space." Another WSU-B student commented that the shared space has been beneficial in providing "informal interactions with people" to "bounce research [ideas] back and forth." Clearly, this common student space has encouraged peer interaction and promoted student socialization to the interdisciplinary community.

Two other interdisciplinary programs in more laboratory-focused disciplines (one each at ESU and WSU) established common laboratory facilities for graduate students and an accompanying course to introduce the students to the facilities and to each other. In both cases, similar socialization benefits were reported, as well as the challenges associated with financial support to continue these initiatives after the external funding period.

Socialization to professional communities

Professional and social relations external to the university are also necessary for graduate socialization, but since the career paths are less defined, these interactions are doubly important in interdisciplinary programs. Students must become familiar with the broader professional context and be able to communicate their expertise to a variety of individuals, within and beyond traditional academic disciplines. Several students mentioned the value of the personal contacts they have been able to make (with future colleagues and even prospective employers) through these external relationships.

As part of an international internship element of ESU-B, one student spent time in Europe working with a top scientist in his field gaining access to "instrumentation" and "expertise that just would not be available" to him in the United States. He stated, the internship

> Gave me some real hands-on training and…really continued to pique my interest…because I am applying for postdocs so that I was able to learn what I want to do the rest of my career or the expertise to get to the point where I can market myself to these more [specialized] labs.

In ESU-A, an external professional resource for students has been the industry trips professors and students take to visit companies working on many of the issues related to their research domain. One benefit of these tours is the potential for employment and/or research funding for future graduates of the program. In addition to a tour of the corporate facilities, professors arranged for students to present their research to industry executives and scientists. According to one ESU-A student, the industry tour was "very interesting, it [provided] really good insight into what kind of research [the company was working on and] how to think about getting a job with them, or in industry in general." In 2008, the industry trip was planned to coincide with a professional conference, and ESU-A students attended as a group. The same student explained that the conference provided an opportunity to "meet people [and] to get to know who they were and [the projects] they were working on." These events provided students with access to crucial professional contacts within academia and industry, as well as additional time to build community and to connect with other ESU-A students and professors. Student socialization is significant within traditional academic disciplinary settings; however, in interdisciplinary research areas with less clearly defined career paths, knowledge of potential employers' expectations—in industry as well as academia—are particularly important for students to find appropriate post-graduation employment (Borrego and Newswander, in press).

University administrative efforts to facilitate socialization

As mentioned earlier, institutional structures and policies often stand as barriers to interdisciplinary research and education efforts. According to graduate deans at both ESU and WSU, the creation and expansion of interdisciplinary graduate education can be a tremendous administrative challenge. To have successful interdisciplinary graduate programs, the former graduate dean at WSU said, "Support [is needed] at multiple levels" of university administration, since "a group of faculty cannot do anything unless they have administrative support." An important aspect of administrative support for interdisciplinary doctoral education is providing opportunities for professors and students to engage in interdisciplinary projects and programs. As a result, the current graduate deans at WSU and ESU have worked closely with others on campus who are supportive of interdisciplinarity.

Significantly, both the former graduate dean at WSU and current graduate dean at ESU recognized that the graduate school/college/division could have a major impact on the success of interdisciplinary graduate education on campus by creating and fostering faculty relationships across the institution. Toward this end, this former WSU administrator emphasized the importance of several new administrative procedures that were put into place to remove some of the "downsides for the faculty" involved in interdisciplinary graduate education. While many of these administrative changes were not explicitly directed at graduate students themselves, she explained that that they were necessary to "improve the experiences of students." This formal administrative support for interdisciplinary graduate education provides improved motivations and/or removes disincentives for professors to create and maintain communities with students and professors beyond their home disciplines.

One of the new administrative policies at WSU designed to improve student access to professors' expertise was creation of a "graduate faculty" system. A former IGERT PI at WSU explained that the graduate faculty allows "any faculty [member] on campus" with "research experience…related to [a specific] field" to "serve as a chair on a dissertation committee." According to the current WSU graduate dean, the graduate faculty system

requires that no doctoral "program be allowed to only have committee members from its own department, that [the committee] ha[s] to be open [to other departments on campus]." She remarked that the graduate faculty "creates more opportunities for students" and professors to "come together and to be part of a bigger vision" of academia. Such a system was designed with students in mind, allowing them greater access to expertise across disciplinary boundaries. The former graduate dean at WSU described the graduate faculty system as "the glue" that "allow[s faculty members from across disciplines] to communicate." Central to these opportunities is the potential for professors and doctoral students to form and strengthen relationships beyond their home disciplines.

At ESU, the Graduate School has also been successful supporting interdisciplinary graduate education in a number of ways. Regarding the impact of current and former IGERT programs on campus, she remarked that "IGERTs model, can model, do model, how interdisciplinary graduate education can work." She has worked with others at the institution to "look at the sustainability of interdisciplinarity" on campus and to facilitate "faculty working across disciplinary lines." Additionally, she has worked toward bringing graduate students from across campus together through the creation of a series of courses related to common issues in academia such as teaching and research. The graduate school encourages "students from different disciplines to come take the courses." According to the ESU graduate dean, one of the goals of these classes is "the creation of a community; it's the creation of people cutting across disciplinary lines… [and to] provide the space, the place and the opportunities for the grad students to interact." In her words, all of these efforts have been successful because "we're breaking down the [disciplinary] silos." Administrators seeking to foster such an environment within the graduate school must acknowledge and seek to mitigate the "high networking costs" (Pfirman et al. 2005) of coordinating with colleagues who have different priorities and participate in different professional societies and conferences.

Discussion

Socialization theory tells us that graduate students need to engage with their peers, supervisors, other professors, and professionals in order to become competent professionals themselves (Weidman et al. 2001). In that sense, these findings are not new, although they demonstrate the transferability of socialization theory to interdisciplinary graduate programs. The primary differences arise from organizational culture, structure and policies that work against interdisciplinarity. In studying graduate student socialization to traditional disciplines, organizational structures are often taken for granted because they have evolved to support disciplinary socialization relatively well. However, structures, policies and reward systems come to the fore in understanding socialization in interdisciplinary programs because universities are ill-equipped to facilitate work integrating traditional disciplines. Professors act as gatekeepers in all graduate programs, but their power and influence increases when they are also one of few sources through which students can find out about interdisciplinary opportunities. The space (laboratory, studio or office) so critical to fostering interdisciplinary community is usually assigned to a disciplinary department rather than interdisciplinary endeavors (and it is nearly impossible to develop a collaboration to the point that need for space is demonstrated without common facilities in the first place). Employers use the schema of disciplinary backgrounds to search for new hires, so applicants with unfamiliar backgrounds could be excluded unless recruiters have first-hand experience with the program and its graduates. At the administrative level, some policies

effectively forbid potential collaborators from working together (e.g., in the case of supervisor and dissertation committee restrictions), while others (e.g., promotion and tenure) are enforced in ways that devalue interdisciplinary work.

Students can be shielded from direct attacks on their research interests, particularly if they are surrounded by supportive peers and mentors. However, many of these students also recognize that they are "academic deviants" (McKenzie and Galar 2004). The experiences of students enrolled in interdisciplinary doctoral programs, particularly those in the U.S., are in many ways a breaking of the traditional 'mold' (Gardner 2008) of doctoral education. Supervisors may need to be even more open with students about the dual cultures of various disciplinary norms and valuing integrated knowledge production, particularly since the colleagues they encounter will be aligned with one or the other to widely varying degrees. It takes a unique type of student to succeed and flourish in these circumstances, which suggests a need to reevaluate what is traditionally meant by student success (Gardner 2009). According to the WSU-A PI, an important aspect of interdisciplinary graduate education is recruiting a different kind of student; one that may not boast exceptional test scores nor a stellar transcript, but breaks the mold of the traditional applicant. For this change to be achieved, professors must explicitly define what it means to be successful within the program. The WSU-A PI explained they seek to recruit students who strike a balance between being too group-oriented where they "[do] not self actualize" and too self-interested where they "[create] so much damage to the social network that it becomes very hard to recover." In this way, WSU-A is not looking for "that one, best, brilliant person" with high GPA and GRE test scores but rather students who have "much better social skills and much better community skills and…are coming here to collaborate." The self-proclaimed "selfish" student—funded by, but not planning to participate in ESU-A—is a case in point. He was likely selected based on high test scores and success in the undergraduate discipline, which have been demonstrated through meta-analyses to be valid predictors of success in disciplinary doctoral programs (Kuncel et al. 2001) designed around individual achievement. That would make him a good fit for a traditional program, but his lack of engagement with interdisciplinary activities is potentially damaging to the network and community that ESU-A leaders are trying to build. For example, Driskell and Salas (1992) found that collectively oriented team members performed better on teams than individually-oriented members, a distinction that is only relevant in an environment that makes frequent use of teams and networks. Otherwise, student responses were generally very positive toward interdisciplinarity, indicating both good fit and a limitation of the study recruiting procedures which likely favored more satisfied students.

In summary, the recommendations are as follows. Professors and administrators interested in supporting interdisciplinary graduate education must seek to jointly identify and cooperatively work toward eliminating institutional barriers which act as disincentives to forming interdisciplinary communities spanning departments, schools and colleges. The graduate faculty system at WSU, which expands eligibility for thesis/dissertation advisors well beyond home department faculty, is an excellent example of this. Physical space is important to the growth of interdisciplinary communities as an area for students and professors to interact with one another and with the tangible artifacts created by the group (Allen 1977; Mallon 2006; Toker and Gray 2008), but faculty must make compelling arguments to support administrators' decisions to assign space to interdisciplinary projects. Finally, as with any socialization process, professors should make the expectations clear, but since interdisciplinarity is not fully accepted in higher education, explicit discussions may be even more critical to students' careers.

An important direction for future work would be to explore how the presence of interdisciplinary programs changes the culture of higher education. This article has demonstrated the many ways in which interdisciplinary work challenges the traditional norms of the academy, but the success of some interdisciplinary programs within and across a number of institutions, coupled with increased funding opportunities, cannot be denied. What effect, if any, do interdisciplinary graduate programs have on the broader institutional culture? Although the uphill battle of changing attitudes related to traditional disciplinary doctoral education was described by one WSU professor "like trying to move a battleship with a stick," he continued, "I feel like the IGERT program over the years at NSF has made a difference" in doctoral education. Others at both institutions also explained that these grants have helped advance interdisciplinary research and graduate education at the institution, including by making collaboration across disciplines more accepted.

The trend toward interdisciplinarity shows signs of increasing in the future, both in academia in general and in doctoral education specifically (Ehrenberg and Kuh 2009). As more doctoral programs become more interdisciplinary in name and nature, the processes and consequences of student socialization will continue to be of great import.

Acknowledgments The authors wish to thank the U.S. National Science Foundation for supporting this work through grant numbers EEC-0643107 and EEC-0648439. The views expressed in this paper are those of the authors and do not necessarily represent those of the National Science Foundation. We are grateful to our participants for taking the time to talk with us and confirm our interpretations, and to Susan Gardner and anonymous peer reviewers for constructive feedback.

References

Allen, T. J. (1977). *Managing the flow of technology: Technology transfer and the dissemination of technological information within the R&D organization*. Cambridge, MA: MIT Press.

Amey, M. J., & Brown, D. F. (2004). *Breaking out of the Box: Interdisciplinary collaboration and faculty work*. Information Age Publishing.

Anderson, M. S. (1996). Collaboration, the doctoral experience, and the departmental environment. *The Review of Higher Education, 19*(3), 305–326.

Austin, A. E. (2002). Preparing the next generation of faculty. *The Journal of Higher Education, 73*(1), 94–122.

Becher, T., & Trowler, P. (2001). *Academic tribes and territories: Intellectual enquiry and the cultures of discipline* (2nd ed.). Buckingham: Open University Press.

Berelson, B. (1960). *Graduate education in the United States*. New York, NY: McGraw-Hill.

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology, 57*(3), 195–203.

Bogdan, R. C., & Biklen, S. K. (2003). *Qualitative research for education: An introduction to theories and methods*. New York, NY: Allyn and Bacon.

Borrego, M., & Cutler, S. (2010). Constructive alignment of interdisciplinary graduate curriculum in engineering and science: An analysis of successful IGERT proposals. *Journal of Engineering Education*, *99*(4), 355–369.

Borrego, M., & Newswander, L. K. (in press). Analysis of interdisciplinary faculty job postings by institutional type, rank, and discipline. *Journal of the Professoriate*, *5*(2).

Boix Mansilla, V., & Dawes Duraisingh, E. (2007). Targeted assessment of students' interdisciplinary work: An empirically grounded framework proposed. *The Journal of Higher Education, 78*(2), 215–237.

Bowen, W. G., & Rudenstine, N. L. (1992). *In pursuit of the Ph.D*. Princeton, NJ: Princeton University Press.

Brainard, J. (2002). U.S. agencies look to interdisciplinary science. *Chronicle of Higher Education* (June 14), A20.

Bromme, R. (2000). Beyond one's own perspective: The psychology of cognitive interdisciplinarity. In P. Weingart & N. Stehr (Eds.), *Practising interdisciplinarity* (pp. 115–133). Toronto: University of Toronto Press.

Carney, J., Chawla, D., Wiley, A., & Young, D. (2006). *Evaluation of the initial impacts of the national science foundation's integrative graduate education and research traineeship program*. Bethesda, MD: Abt Associates, Inc.

Committee on Facilitating Interdisciplinary Research. (2005). *Facilitating interdisciplinary research*. Washington, DC: The National Academies Press.

Creswell, J. W. (2007). *Qualitative inquiry & research design: Choosing among five approaches*. Thousand Oaks, CA: Sage Publications.

Donald, J. (2002). *Learning to think: Disciplinary perspectives*. San Francisco: Jossey-Bass.

Driskell, J. E., & Salas, E. (1992). Collective behavior and team performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 34*(3), 277–288.

Ehrenberg, R. G., & Kuh, C. V. (2009). Looking to the future. In R. G. Ehrenberg & C. V. Kuh (Eds.), *Doctoral education and the faculty of the future*. Ithaca, NY: Cornell University Press.

Gardner, S. K. (2007). ''I heard it through the grapevine'': Doctoral student socialization in chemistry and history. *Higher Education, 54*, 723–740.

Gardner, S. K. (2008). Fitting the mold of graduate school: A qualitative study of socialization in doctoral education. *Innovative Higher Education, 33*(1), 125–138.

Gardner, S. K. (2009). Conceptualizing success in doctoral education: Perspectives of faculty om seven disciplines. *The Review of Higher Education, 32*(3), 383–406.

Golde, C. M. (1998). Beginning graduate school: Explaning first-year doctoral attrition. In M. S. Anderson (Ed.), *The experience of being in graduate school: An exploration*. San Franciso, CA: Jossey-Bass.

Golde, C. M. (2005). The role of the department and discipline in doctoral student attrition: Lessons from four departments. *Journal of Higher Education, 76*(6), 669–700.

Golde, C. M., & Gallagher, H. A. (1999). The challenges of conducting interdisciplinary research in traditional doctoral programs. *Ecosystems, 2*, 281–285.

Golde, C. M., & Walker, G. E. (Eds.). (2006). *Envisioning the future of doctoral education: Preparing stewards of the discipline. Carnegie essays on the doctorate*. San Franciso, CA: Jossey-Bass.

Gooch, J. C. (2005). The dynamics and challenges of interdisciplinary collaboration: A case study of "cortical depth of bench" in group proposal writing. *IEEE Transactions on Professional Communication, 48*(2), 177–190.

Graybill, J. K., Dooling, S., Shandas, V., Withey, J., Greve, A., & Simon, G. L. (2006). A rough guide to interdisciplinarity: Graduate student perspectives. *BioScience, 56*(9), 757–763.

Gumport, P. J. (1993a). Graduate education and organized research in the United States. In B. R. Clark (Ed.), *The research foundations of graduate education: Germany, Britain, France, United States, Japan* (pp. 225–260). Berkeley: University of California Press.

Gumport, P. J. (1993b). Graduate education and research imperatives: Views from American campuses. In B. R. Clark (Ed.), *The research foundations of graduate education: Germany, Britain, France, United States, Japan* (pp. 261–293). Berkeley: University of California Press.

Heiss, A. M. (1970). *Challenges to graduate schools*. San Francisco, CA: Jossey-Bass.

Holley, K. (2009). The challenge of an interdisciplinary curriculum: A cultural analysis of a doctoral-degree program in neuroscience. *Higher Education, 58*, 241–255.

Hrycyshyn, G. (2008). *Challenges to implementation & how they were overcome: 2006–2007 IGERT annual report*. Arlington, VA: National Science Foundation.

Klein, J. T. (1990). *Interdisciplinarity: History, theory, and practice*. Detroit: Wayne State University Press.

Kuncel, N. R., Hezlett, S. A., & Ones, D. S. (2001). A comprehensive meta-analysis of the predictive validity of the Graduate Record Examinations: Implications for graduate student selection and performance. *Psychological Bulletin, 127*(1), 162–181.

Lamancusa, J. S., Jorgensen, J. E., Zayas-Castro, J. L., & Ratner, J. (1995). *THE LEARNING FACTORY–A new approach to integrating design and manufacturing into engineering curricula.* Paper presented at the American Society for Engineering Education Annual Conference, Anaheim, CA.

Lattuca, L. R. (2001). *Creating interdisciplinarity: Interdisciplinary research and teaching among college and university faculty*. Nashville, TN: Vanderbilt University Press.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Lovitts, B. E. (2001). *Leaving the ivory tower: The consequences of departure from doctoral study*. Lanham, MD: Rowman and Littlefield.

Mallon, W. T. (2006). The benefits and challenges of research centers and institutes in academic medicine: Findings from six universities and their medical schools. *Academic Medicine, 81*(6), 502–512.

McKenzie, R. B., & Galar, R. (2004). The importance of deviance in intellectual development. *The American Journal of Economics and Sociology, 63*(1), 19–49.
National Institutes of Health. (2006). NIH roadmap for medical research. Bethesda, MD.
National Science Foundation. (2006). *National science foundation investing in America's future strategic plan FY 2006–2011*. VA: Arlington.
National Science Foundation. (2010). *Integrative graduate education and research traineeship program (IGERT)*. VA: Arlington.
Nerad, M., & Miller, D. S. (1996). Increasing student retention in graduate and professional programs. In J. G. Haworth (Ed.), *Assessing graduate and professional education: Current realities, future prospects* (Vol. 42, pp. 61–76). San Francisco, CA: Jossey-Bass.
Oberg, G. (2009). Facilitating interdisciplinary work: Using quality assessment to create common ground. *Higher Education, 57*, 405–415.
Patton, M. Q. (2002). *Qualitative research & evaluation methods*. Thousand Oaks: Sage Publications.
Payton, A., & Zoback, M. L. (2007). The inside track from academia and industry: Crossing boundaries, hitting barriers. *Nature, 445*(22), 950.
Pfeffer, J. (1993). Barriers to the advance of organizational science: Paradigm development as a dependent variable. *The Academy of Management Review, 18*(4), 599–620.
Pfirman, S. L., Collins, J. P., Lowes, S., & Michaels, A. F. (2005). To thrive and prosper: Hiring, fostering and tenuring interdisciplinary scholars. Project Kaleidoscope Resource.
Reich, S. M., & Reich, J. A. (2006). Cultural competence in interdisciplinary collaborations: A method for respecting diversity in research partnerships. *American Journal of Community Psychology, 38*(1), 51–62.
Repko, A. F. (2008). *Interdisciplinary research*. Thousand Oaks, CA: SAGE.
Sa, C. M. (2008). 'Interdisciplinary strategies' in U.S. research universities. *Higher Education, 55*, 537–552.
Salter, L., & Hearn, A. (1996). *Outside the lines*. Montreal & Kingston: McGill-Queen's University Press.
The Woodrow Wilson National Fellowship Foundation. (2005). The responsive Ph.D.: Innovations in U.S. doctoral education.
Tierney, W. G. (1997). Organizational socialization in higher education. *Journal of Higher Education, 68*(1), 1–16.
Tierney, W. G. (2008). *The impact of culture on organizational decision-making: Theory and practice in higher education* (1st ed.). Sterling, VA: Stylus Pub.
Toker, U., & Gray, D. O. (2008). Innovation spaces: Workspace planning and innovation in U.S. university research centers. *Research Policy, 37*, 309–329.
Tress, B., Tress, G., & Fry, G. (2009). Integrative research on environmental and landscape change: PhD students' motivations and challenges. *Journal of Environmental Management, 90*(9), 2921–2929. doi: 10.1016/j.jenvman.2008.03.015.
Turner, J. L., Miller, M., & Mitchell-Kernan, C. (2002). Disciplinary cultures and graduate education. *Emergences, 12*(1), 47–70.
Van Hartesveldt, C., & Giordan, J. (2008). Impact of transformative interdisciplinary research and graduate education on academic institutions: National Science Foundation.
Walker, G. E., Golde, C. M., Jones, L., Bueschel, A. C., & Hutchings, P. (2008). *The formation of scholars: Rethinking doctoral education for the twenty-first century*. San Francisco: Jossey-Bass.
Weidman, J. C. (1989). Undergraduate socialization: A conceptual approach. In J. C. Smart (Ed.), *Higher education: Handbook of theory and research* (Vol. 5, pp. 289–322). New York, NY: Agathon.
Weidman, J. C., Twale, D. J., & Stein, E. L. (2001). *Socialization of graduate and professional students in higher education: A perilous passage? (Vol. 28)*. San Francisco: Jossey-Bass.