

The challenge of an interdisciplinary curriculum: a cultural analysis of a doctoral-degree program in neuroscience

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Abstract Drawing on data collected through 45 interviews with faculty, doctoral students, and administrators affiliated with an interdisciplinary neuroscience program, I examine the structure of the interdisciplinary graduate curriculum. The data presented here highlight the challenge of such programs. I review the purpose, organization, and content of the interdisciplinary curriculum, noting those challenges that arise. Not only do such programs require collaboration among faculty who traditionally has been highly invested in their individual discipline or department, but they also require an active, deliberate process to foster interdisciplinary integration and student learning.

Keywords Curriculum · Graduate education · Interdisciplinarity · Culture · Qualitative research

The field of neuroscience has experienced rapid growth in American universities over the last three decades. Much of this growth has been interdisciplinary in origin. Originally located in schools of medicine or colleges of arts and sciences, contemporary neuroscience programs commonly span across the university, linking scientists from multiple departments (Association of Neuroscience Departments and Programs 2005). The challenge for neuroscience education is to provide a depth of knowledge and training from various fields of study. In particular, faculty and researchers within the field have debated the possibilities in regards to interdisciplinary neuroscience programs for doctoral students (Hall 2004). The interdisciplinary perspective represents a radical departure from the traditional structure of the Ph.D. in American higher education.

Doctoral education develops disciplinary expertise on behalf of students and presumes the discipline as the point of origin (Golde and Walker 2006). Graduate students are trained to engage in systematic research, extend the disciplinary body of knowledge, and develop questions that are important to other practitioners within the discipline (Hutchings and

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Clarke 2004). The disciplinary tradition focuses on the cultural practices of the field as well as the content knowledge relevant to practitioners. An interdisciplinary curriculum, however, moves beyond the single disciplinary focus, instead presenting an integration of various perspectives focused on a shared problem or research question. Drawing on data collected through 45 interviews with faculty, doctoral students, and administrators affiliated with an interdisciplinary neuroscience program, I examine the structure of the interdisciplinary graduate curriculum. I do so by focusing on a cultural understanding of the interdisciplinary process as experienced by students and faculty affiliated with the program. The research questions examined in this study are: What challenges exist in terms of the organization of an interdisciplinary graduate curriculum? What strategies facilitate the delivery of such a curriculum?

I briefly summarize the relevance of culture to this analysis. Culture relates to the process of meaning making by individuals within a specific community (Spillman 2002). The goal of studying culture is to understand how people interpret and order the world with an emphasis on how individual interpretation impacts social life. Culture offers a variable and contingent framework to understand individual and group behavior according to the context. Such an approach has been frequently applied to analyze the disciplines. For example, Becher and Trowler (2001) examined the academic disciplines as a form of culture. “By culture,” the authors noted, “we refer to sets of taken-for-granted values, attitudes, and ways of behaving which are articulated through and reinforced by recurrent practices among a group of people in a given context” (p. 23). Describing the disciplines as tribes and territories, Becher and Trowler argued that individuals make sense out of various cultures through disciplinary norms, reflected through the curriculum, research practices, and other cultural artifacts. These rituals, values, and beliefs enable scholars to construct meaning as a member of the discipline. Clark (1983) noted that each discipline exhibits “a way of life into which new members are gradually inducted” (p. 76). Disciplinary membership results in a “deep sense of being different from others, including scholars in bordering fields” (Clark, p. 77). The disciplines represent groups of individuals clustered around shared knowledge tasks, each occupying a space within the university structure.

Membership in an interdisciplinary community challenges the long-accepted structure of the academy. The goal of an interdisciplinary curriculum is to train future scholars and practitioners who can bridge multiple disciplines in their work. These students not only gain fluency in the ideas and language of various disciplines, but also in the behaviors expected of various disciplinary communities. This challenge is unique to an interdisciplinary curriculum. Rather than demonstrating expertise in a specific, single field of inquiry, interdisciplinary scholars confront the need for fluency in multiple fields. Two conflicts emerge between the idealized and enacted interdisciplinary curriculum. First, the curriculum is delivered as part of a disciplinary organization, the university. The organizational culture of the university is one divided by disciplinary ways of thinking and behaving. Second, the faculty responsible for delivering the interdisciplinary curriculum are themselves likely trained in a disciplinary field. These challenges require unique organizational and pedagogical strategies.

The production of knowledge is not solely limited to the university structure. Defined as Mode 2 knowledge by Gibbons et al. (1994), contemporary knowledge is frequently fostered through broad, transdisciplinary contexts. Such efforts involve “more actors who come from different disciplines and backgrounds... [and] different sites in which knowledge is being produced,” Gibbons et al. noted (p. 17). In terms of interdisciplinary graduate education, it is important to recognize that the curriculum is not a strict dichotomy between disciplinary and interdisciplinary efforts. Transdisciplinary work draws scholars outside

the academy and relies on a fluid, flexible approach towards problem solving. Doctoral students are increasingly confronted with the reality of a dynamic and volatile configuration towards research (Gibbons 1999; Nowotny 2003). An interdisciplinary curriculum for graduate education represents but one of multiple converging influences impacting university behavior.

Before I turn to my analysis, I outline the conceptual framework utilized for this article, which examines the curriculum as representing the knowledge of value to the disciplinary community. Because of its significance as both a cultural artifact and a social process, the curriculum serves as a useful area of analysis in order to understand academic behavior. I summarize the research context and methodology before detailing the experience of an interdisciplinary graduate curriculum. I conclude with implications for the theory and practice of interdisciplinary education.

Conceptual framework

I consider the curriculum as an area for cultural analysis of the disciplines and the development of an interdisciplinary field. The curriculum represents a course of study or training program in a particular field that structures student learning (Donald 1986; Oliva 1997). More than simply the sum of knowledge reflected through a course design or class syllabi, the curriculum is a social process shaped by power and participation, and represents the influence of multiple factors, such as the faculty, the discipline, the student, the institution, and various external constituencies (Banks 1993; Tierney 1989). The curriculum works to define what counts as knowledge, and consequently influences the behavior and beliefs of members. Ultimately, the curriculum represents a form of culture specific to the community—it is an act of discourse embedded within a specific context. Viewed from a cultural perspective, an analysis of disciplinary curricula offers insight into how knowledge is prioritized and ordered by academics. The formal component of the curriculum occurs in the classroom, as the students and instructor collectively construct knowledge related to particular topics. Yet the curriculum also works more broadly throughout the discipline. Through larger, more tacit traditions such as engagement in research and the organization of academic programs, knowledge production practices are situated within the community. The curriculum determines perspectives and forms of knowledge that are to be prioritized as the disciplinary norm.

In graduate education, such forms of knowledge are significant in establishing the traditions and future development of the discipline. The acquisition of knowledge enables students to participate as active members of the community and produce future research of value to the discipline. Students engage in the formal or written curriculum primarily through required and elective coursework. The informal curriculum is assumed to occur outside the classroom. For graduate students, the informal curriculum includes research assistantships, participation in conferences, and co-authoring papers with faculty. Such activities socialize students into the norms and values of the academic discipline. Students identify behaviors congruent to a member of the community, and shape their participation based on these beliefs (Golde 2000). Faculty and peers serve as anchors for students to master the knowledge perceived to be vital to the disciplinary community. The challenge for faculty is not only to define and prioritize content, but also to recognize new bodies of knowledge as they emerge. With the dynamic growth and availability of knowledge, faculty members continually confront the question of *what* knowledge students should be expected to master. In part due to disciplinary traditions and unique cultural influences,

disciplinary curricula reflect differences in the “kinds of concepts used and the nature of those concepts, the logical structure of the discipline, the truth criteria used, and the methods important in each area” (Donald 1986, p. 279).

Walker (2003) defined the curriculum as “a particular way of ordering content and purposes for teaching and learning” (p. 5). Utilizing this definition, curricular analyses emphasize not only the outcome of such efforts (the cultural artifact), but also efforts involved to produce such an outcome (the social process). The social process occurs as part of the relationships between the faculty and students as well as between various groups of faculty. Walker (2003) identified the curriculum through its three primary components: purpose, organization, and content. I consider these three components in relation to the traditional graduate curriculum.

Purpose

The purpose of the graduate curriculum in American higher education is to train scholars within a disciplinary community. Golde and Walker (2006, p. 5) noted that such individuals are expected to “creatively generate new knowledge, critically conserve valuable and useful ideas, and transform those understandings through writing, teaching and application.” Students build upon a disciplinary foundation, acquiring greater and more specialized depth of content knowledge, as they progress through the program. This competence allows students to discriminate among a vast body of scholarly literature and actively apply such skills to generate new knowledge. Content knowledge is enhanced through the acquisition of professional skills, including grant writing, collaborative research, and communication across a range of audiences. The faculty assume the *de facto* role of arbitrators of the disciplinary curriculum. Through an analysis of the faculty role, the significance of the curriculum as a social process becomes apparent. Curricula are sites of social interaction between faculty, doctoral students, and significant cultural components, such as research laboratories or primary textbooks. Doctoral curricula are structured to enhance the interaction between faculty and students, fostering a disciplinary community in which the student becomes engaged. Disciplinary practices assume a normative appearance through these interactions.

Contemporary economic and social influences have strained the dominant foundation of graduate education in American universities. Specifically, the disciplinary basis of doctoral programs as well as the assumption that such programs provide a linear path to an academic faculty career have been called into question. Historically, graduate education has served to train future generations of faculty. Such programs have also been central to the integration of teaching and research that is fundamental to higher education (Gumport 1994). “The specialization of disciplines that was mirrored by departments represented professors’ vocational aspirations,” concluded Gumport (1994, p. 312). Federal funding supported the training of graduate students through engagement with basic research, especially in the sciences. For almost a century, the purpose of the American graduate curriculum was to enable students to contribute to the growth of the discipline, engage in teaching activities, and produce research of value to the nation.

Graduate students are increasingly viewed as both students and employees of higher education (Dixon et al. 2008; Rhoades and Rhoads 2003). While the idealized purpose of the graduate curriculum remains largely stagnant, graduate students are confronted by an uncertain academic labor market. The type of employment available to—and pursued by—graduates is questioned (Austin 2002; Gaff 2002). In some disciplines, such as the natural and laboratory sciences, a strong preference exists for nonacademic or academic research

careers compared to academic teaching for students (Fox and Stephan 2001). In addition, faculty members rely on competitive and frequently elusive funding to engage in knowledge production. Some critics argue that, rather than being trained as independent scholars and future faculty, graduate students are instead seen as technicians-for-hire (Gumport 1994; Mendoza 2007). Faculty no longer serve as mentors and facilitators for student learning, but rather as project managers and supervisors.

Organization

The graduate curriculum has historically been organized to train students for membership within the discipline. Students are commonly expected to master basic, or core knowledge, through a sequential series of courses. These courses represent the foundational knowledge of the discipline. After students complete a core, introductory curriculum, they demonstrate a rudimentary fluency with the literature of the discipline. Students spend their latter years in the program specializing in particular aspects of the field through additional coursework and research experience. While academic disciplines vary in their perspective towards the doctoral dissertation, the process serves as a culminating event of the graduate school curriculum, signifying that the student is capable of working as an independent researcher within the field. The relationship between doctoral students and faculty assumes a more individualized nature as the student progresses through the curriculum. This relationship provides the most powerful influence on student development throughout the doctoral program (Katz and Hartnett 1976; Paglis et al. 2006; Weidman and Stein 2003). This influence is not always positive. “Powerful pressures are at work in an academic setting toward maintenance of the status quo,” argued Bargar and Mayo-Chamberlain (1983, p. 418). “Conflicts in [intellectual] perspective... may prove to be exercises in personal power and ego protection.”

Just as research and grant funding are increasingly prioritized for faculty members, so do graduate students experience changes brought about by the volatile relationship between higher education and various external constituencies (Mendoza 2007). Faculty hold the primary responsibility for funding their research. Given the connection between the faculty and graduate students, it is not surprising that the organization of the graduate curriculum contributes to this mechanism. In those disciplines that rely most heavily on external grant funding to support research activities, graduate students are almost immediately immersed in laboratory work and other research endeavors. The pedagogic emphasis on research practices has long been reflected in the natural and laboratory science disciplines (Campbell 2003). When viewed from a cultural lens, however, the indifference towards the formal content curriculum in favor of research raises questions about the significance of disciplinary knowledge in graduate education. Such behavior also supports the supremacy of research as the *raison d’être* of higher education. Disciplinary cultures, particularly in the science fields, increasingly reproduce themselves not through the dissemination of disciplinary knowledge, but rather the training of researchers.

Content

The curricular content of the doctoral curriculum is highly correlated with the idea of intellectual mastery. During the first few years of the program, faculty systematically present an array of authors, concepts, and events significant to understanding the discipline. The primary influences on course planning are the background, discipline, and educational beliefs of the faculty (Stark et al. 1997). These influences are specific to the nature of the

disciplines. For example, Lattuca and Stark (1994) noted that faculty in natural science disciplines generally exhibit a greater consensus on course content, and are more inclined to accept administrative coordination of course sequences. Questions of content include outlining specific domains of knowledge relevant for student learning as well as prioritizing such content. Introductory coursework serves as a framework for subsequent classes, while core topics provide a foundation for student learning. Beyond the mastery of content, the doctoral curriculum demands facility with theory, method, and synthesis. The process of enacting the content of the curriculum occurs as a negotiation between faculty and students: the former, relying on disciplinary expertise and experience; the latter, bringing previous educational experiences and perceptions into the graduate classroom (Snyder et al. 1992). Faculty members play a direct role in the students' interpretation of the knowledge content. This role is particularly apparent in the dissertation topics and research agendas constructed by graduate students. In the natural and laboratory science disciplines, graduate students identify a faculty advisor early in their doctoral program. Their research activities commonly reflect the agenda of the advisor.

Research design

I utilized a qualitative, descriptive case study (Merriam 1998) to examine an interdisciplinary graduate curriculum in neuroscience. I approached the data analysis for this study from a cultural perspective, defined by Geertz (1973, p. 20) as “sorting out the structures of signification...and determining their social ground or import.” Culture is an elusive concept, negotiated through the actions and interactions of individuals, and by the interpretation of their words, behaviors, and meanings. I developed questions regarding the formal classroom curricula, research practices, and the administration of the interdisciplinary program. The emphasis of a curricular analysis is not only the content knowledge, but also how that knowledge is enacted and interpreted by participants. I therefore specifically focused on issues of interaction, power, and relationships in the interdisciplinary program. For example, I asked students how content knowledge gained through the curriculum was manifested through their research as well as which individuals they interacted with on a daily basis. Faculty explained their perceptions of the interdisciplinary features of the program in addition to knowledge they expected all students in the program to master.

Data for this study was collected over a 10-month time span. The data collection was focused on the individuals directly affiliated with the neuroscience program. I interviewed 45 faculty, doctoral students, and administrators. Over half (53%) of the students were women, and 13 were international students. The faculty interviews included the neuroscience program director as well as those individuals who taught or advised in the program. Each of the student and faculty interviews lasted for ~1 h. With individual consent, I audiotaped and transcribed each interview. After transcription, I offered each participant the opportunity to read the transcript for additional comments or clarification.

The inherently interrelated nature of the qualitative research process means that “data analysis” is not a grand act reserved for the end of data collection, but rather an ongoing, continually evolving process. The qualitative software NVivo was used to organize, manage, and analyze interview transcripts. I employed an inductive analytic approach (Cresswell 1994; Strauss and Corbin 1998) informed by previous research on curriculum, the disciplines, and interdisciplinarity that allowed me to search for patterns of meaning in the interview data. Frames of analysis related to the curriculum and interdisciplinarity were

identified early in the research study. For example, the student interview protocol focused on experiences in the core (formal) curriculum, the laboratory, and with peers and faculty from multiple disciplines. I also grouped transcripts according to the individual's affiliation with one of five areas of neuroscience research at the institution, searching for similarities and differences among these subcultures. After each interview, I analyzed the transcript to identify important concepts. Data drawn from interview transcripts were broken down into discrete codes. Systematic comparison across the various codes focused on similarities and differences within the data (Hatch 2002). This comparison resulted in themes by which I organized my conclusions. Students and faculty provided feedback on the development of emergent themes and categories, which contributed to the trustworthiness of the data.

Program context

This study was conducted at an American 4-year, private institution (referred to as Eastern Research University, or ERU, in order to ensure confidentiality) defined by the recent Carnegie classifications as a university with very high research activity. The program consists of ~65 faculty from across the institution who are affiliated with one of five major research areas. The faculty represent 18 different departments, colleges, and schools. The interdisciplinary neuroscience program at ERU has evolved over the last 25 years. In the early 1980s, a core group of faculty from the biology department expressed an interest in the development of an interdisciplinary program in neuroscience. At that time, the department offered a Ph.D. degree; students could specialize in cellular, molecular, or neural biology. Along with faculty in psychology, the neurobiology faculty formed much of the original framework for the doctoral program in neuroscience. The program has consistently ranked among the top thirty such programs in the United States, and has become increasingly selective in regards to student admission.

The mission of the neuroscience program at ERU is twofold. First, according to the faculty director, the program supports “traditionally funded individual investigator driven research programs,” which are “the foundations on which [ERU] can build interdisciplinary research bridges.” In addition, the program provides infrastructure and support to “organize novel interdisciplinary research and training programs.” The interdisciplinary program, according to its director, fosters research “in a way that individual departments cannot.” Some of this strength is a result of the extensive network of faculty involved in the program. The program includes faculty representing multiple departments, school, and research institutes, including biology, psychology, linguistics, computer science, biomedical engineering, psychiatry, pharmacy, medicine, and gerontology. Key funding for the program has long been garnered from the Office of the Provost, although the program faculty are increasingly expected to procure research grants to support graduate assistants. The program is seen as an exemplary model of interdisciplinary research at ERU, and is an integral component of the institution's science strategy.

Results

I utilize the major components of the curriculum as identified by Walker (2003) to order my three main findings. First, the purpose of the interdisciplinary graduate program was to train students as part of an integrated, collaborative curriculum. Some confusion existed at ERU in regards to identifying, structuring, and delivering the primary bodies of knowledge crucial to an interdisciplinary understanding of the field. Second, the organization of the

interdisciplinary program encouraged students to gain research experience as well as additional content knowledge through disciplinary electives. The electives served to provide a range of exposure to various fields. Third, the content knowledge in the interdisciplinary curriculum was not only strongly determined by the faculty affiliated with the program, but also by the cultural and social influences that existed at ERU.

Purpose of an interdisciplinary graduate curriculum

According to ERU neuroscience recruitment materials, the purpose of an interdisciplinary graduate curriculum is to prepare students for “collaborative interactions...working at many different levels of analysis.” As a result, doctoral students engaged in a purposive “broad-based curriculum” which represented a “highly interdisciplinary approach to understanding neural function.” The interdisciplinary neuroscience curriculum fostered a sense of an innovative, creative learning community. For example, first-year students not only completed a required core course, but also engaged with faculty and other students through weekly seminars, social functions, and special lectures. Affiliated faculty and students took great pride in the forward-thinking nature of their work. One psychology professor noted, “I think the interdisciplinary study of the brain is one of the world’s greatest problems. This program is on the cutting edge of that.” Students echoed this professor’s comments; several students explained that they were attracted to the program by the innovative, progressive nature of an interdisciplinary field. Similar to traditional doctoral programs in the disciplines, the interdisciplinary neuroscience program featured a delicate balance between research and classroom learning. The faculty director of the program explained, “Our goal is to get students into the lab to conduct research as quickly as possible. We want our curriculum to provide them with the tools they need to do that.”

The conflict of an interdisciplinary curriculum within the disciplinary structure of the university was significant. One area in which the ERU neuroscience program experienced particular challenges was the first-year, required core curriculum. All first-year students are required to complete a two-semester core course. The goal of the course was to give a “broad understanding of basic concepts in biological, cognitive, and modeling approaches to brain structure and function.” The course was divided into eight modules, designed to offer students a basic introduction to the many different areas of the interdisciplinary field. One first-year student summarized the course as “you get a flavor of neuroscience, a sense of what is in the water.” For many students, the course was the only experience they had working with the many different constituent disciplines of the field. “Working in the core course, you really get a sense for how interdisciplinary the curriculum is,” another first-year student concluded.

Faculty remained strongly divided over the content, structure, and implementation of the first-year course. For example, a professor of biomedical engineering explained, “The neuroscience students cover in 2 weeks what we spend a semester on in my [traditional] course. Even though it’s a year-long course, they cover so many areas in a very short period of time.” A professor psychology who teaches a module in the course explained his approach. “[My field] is such a broad area, you can wind up doing it really superficially and not learning much, or you can really get a feel for the paradigm,” he said. His solution was to solely use his own research as the basis for content in the class module. “I said we were just going to concentrate on [this area] and I explained why—that it is the most advanced, and the area I know best.”

Little active discussion occurred in regards to the best way to identify and integrate fundamental topics related to the interdisciplinary study of neuroscience. Beyond defining

the broad topic of the eight modules that students must complete, the content of the course was almost exclusively determined by the faculty instructor. Most students expressed reservations over the purpose of the core course to provide foundational knowledge for the interdisciplinary field. Students expected that the core curriculum would provide a basic understanding of the broad, interdisciplinary field. Yet as one-second-year student recounted, “It was a drive-through learning experience, where you became an expert in whatever PowerPoints were put on the board.” His classmate agreed, noting “We learned the one theory that was the professor’s specialty. It was frustrating.”

Organization of an interdisciplinary graduate curriculum

The interdisciplinary neuroscience curriculum featured a loosely designed formal curriculum, supplemented by an intense, early immersion in laboratory research. This structure is reflective of traditional graduate programs in the natural and laboratory sciences. In keeping with the program mission to have students working as part of a research team as soon as possible, required coursework was kept to a minimum. Other than the first-year core course and a supplemental seminar, students in the neuroscience program completed the majority of their coursework through elective classes. These classes were usually offered through a department affiliated with the neuroscience program, although students could complete any graduate-level course at the university to meet their degree requirements. Neither faculty nor students seemed enthusiastic about the structure of the program. The program’s faculty director said, “The curriculum is wholly inadequate.” Instead of spending time in the classroom to master interdisciplinary content, he explained, students are instead pressured to commit early to the work of a specific research laboratory.

Faculty in general supported the early immersion of students in the research laboratory. “They think you should learn to do the research, and take the minimum number of courses,” one-fifth-year student explained. Her classmate added, “The idea here is to get students into the lab as quickly as they can, and that kind of isolates you, and forces you to do your own thing.” One student nearing completion of her dissertation said, “I think it’s just that they really want us to be in the lab, and they want us to learn how to really be scientists instead of studying the books. They want us to be more hands-on, thinking about and designing experiments.” She concluded, “I would kind of want one or two more lectures. I miss the rigor that comes with classwork.” The organization of the curriculum meant that students “learned” how to be interdisciplinary scholars through engaging in laboratory research rather than formal classroom experiences. Yet the nature of laboratory research is to develop a focus on one aspect of a larger research agenda, often eliminating connections to other related topics.

Students noted that the rich array of possible electives was disorientating. Little advice was offered to students in terms of what electives to take by the program staff. Students noted that advisors and peers had limited input as well. Many students said that they expected the elective curriculum to provide the content that was missing from the first-year core curriculum. “I can take a class in computational physics, because there are so many physics theories that can be applied to the brain,” one second-year student explained. “You can go to computer science and take a brain theory class, BME and take a biophysics class. The program says we can be done when we want, but if there is a good class out there, I want to take it.” The same student concluded, “I don’t think there should be more courses in the program, but the electives need to be more structured.” Students also expressed uncertainty over the value of their elective coursework, and how they should select such courses to foster interdisciplinary learning. One international student who worked in

computational neuroscience explained that his electives primarily consisted of coursework in computer science. But he added, “I will only audit the course [when I can]. I don’t want to take any exams. It takes too much time to study when I need to be in the lab.”

Faculty advisors exerted some influence in regards to student elective courses. For example, one-second-year student in computational neuroscience explained her interest in coursework related to artificial intelligence. “[My advisor] said I would probably get enough of that in the lab, so I didn’t need to go to another department and get it,” she concluded. “I really don’t know what else I should take, because a lot of the courses [in biology] are not relevant for my research or my interests.” The lack of emphasis on formal course content resulted in interdisciplinary learning experiences being perceived as removed from the classroom. The student felt that the lack of elective coursework was a weakness in the interdisciplinary curriculum. “For the research I am doing, I need a lot of information, and not necessarily a lot of [research techniques]. You don’t get that with three required courses and all electives.” More often than the faculty advisor, students noted that their classmates and laboratory colleagues offered advice in regards to what elective classes to take. “Actually, I get a lot of input from other girls in my lab,” a first-year student admitted. “My PI is really busy.”

Content of an interdisciplinary graduate curriculum

The purpose of the ERU interdisciplinary neuroscience program is to prepare students to work as part of a collaborative research team, demonstrating a facility with multiple levels of analysis. The first-year required core curriculum was the hallmark of the program’s approach. “On paper, if we do the [core course] right, then students should have some exposure, and be able to intelligently understand something,” said one psychology professor. He added, “You don’t know where the boundaries are to what you are doing in your work. So it’s nice to be able to make connections between bodies of knowledge as well as groups of people.” The loosely structured nature of the core and elective courses, however, served to limit the amount of content knowledge to which students are formally exposed to in the program. An interdisciplinary curriculum requires that similar content knowledge be integrated as part of student learning. The crucial element of integration was lacking at ERU, resulting in what one professor called a “smattering” of neuroscience-related information that doctoral students received during their first year. Instead of pursuing an integrated depth of knowledge through a well-designed elective curriculum, students were instead encouraged to immerse themselves in laboratory research. “I think if you take eight or ten hard courses in graduate school, as opposed to one or two, you know more. Here, taking courses as a whole is just something that is frowned upon—although not by me,” said a biomedical engineering professor.

Even though faculty typically worked with doctoral students enrolled in different degree programs in their research laboratory, little distinction existed in terms of faculty expectations. For example, one professor of psychology, who was jointly appointed to the computer science department, worked with doctoral students from neuroscience, psychology, and cognitive science as part of a research team. “They are indistinguishable,” he concluded. “What we do, you wouldn’t know what program they are in. It’s the same problem, the same range, and they have the same training.” Another faculty in developmental psychology agreed. “Some students will be more on the cognitive or psychological side of neuroscience, while others will work with the neuroscience side of psychology. It doesn’t really matter in terms of the degree program they are enrolled in.” A professor in biomedical engineering concluded, “The only difference between the students is the

difference you would see between any two people. [The program they are enrolled in] never occurs to me.” These findings suggest that the active practice of interdisciplinarity was not an overt cultural component of the ERU neuroscience program. Often students were expected to identify and pursue their own interdisciplinary interests within the program’s structure.

In addition to faculty expectations, cultural influences also shaped the content and direction of the curriculum. The biology department at ERU remained the primary influence in terms of the direction, organization, and administration of the interdisciplinary neuroscience program. Two reasons existed for this influence. First, the biology department served as the catalyst for the neuroscience program over two decades ago. According to the neuroscience program faculty director, the biology department is the “historic center of the neuro-universe” at the university, and is the “main player” in terms of neuroscience program funding and administration. “Much of the tension that exists in this program today is because of our relationship with the biology department,” he concluded. “They still feel much responsibility for our program, and shoulder much of the funding burden.” Second, the content knowledge of biology is considered central to an understanding of neuroscience. As a biomedical engineering professor explained, “The people in biology, those we used to call neurobiologists, that’s pretty central. They study the brain and how it works. People like me, who are in engineering, are not purely neuroscientists. They don’t have as their only activity the study of the brain.” While the program was interdisciplinary in terms of faculty affiliation, the impact of the interdisciplinary curriculum was limited by the cultural and organizational characteristics of ERU.

The biological emphasis as part of the interdisciplinary graduate curriculum in neuroscience was particularly challenging for those students who entered the program with little or no background in the biological sciences. Because of the range of the interdisciplinary field, some students were interested in neurolinguistics, neuroimaging, or neural engineering, which required training in an array of disciplines. “I’m definitely on the periphery in the program, because I don’t study the harder, more biological aspects of neuroscience,” one student in neurolinguistics confided. Other students noted that the lack of prerequisites for the program limited the impact of the core curriculum. “We don’t have specifically any kind of anatomy prerequisite. The components of the brain are not defined or concrete, so an anatomy course would have enabled me to understand ‘That is here, versus there’.”

Discussion

The data presented here highlight the challenge of an interdisciplinary graduate curriculum. Not only do such programs require collaboration among faculty who traditionally have been highly invested in their individual discipline or department, but they also require an active, deliberate process to foster interdisciplinary integration. I return to the two research questions which guided this study: What challenges exist in terms of the organization of an interdisciplinary graduate curriculum? What strategies facilitate the delivery of such a curriculum?

For an interdisciplinary curriculum, such as the neuroscience program at ERU, the classroom reflected the challenge for faculty from multiple disciplines to decide upon cognitive elements crucial to interdisciplinary practice. The faculty did not agree on what knowledge elements comprised the “core” interdisciplinary learning experience in neuroscience nor the delivery method best suited for interdisciplinary education. Perhaps more significantly, the conversation among faculty needed to ensure a well-designed

interdisciplinary curriculum did not occur. The first-year core curriculum was designed to provide all entering doctoral students with an exposure to the breadth of the interdisciplinary field. Because the students entered the program with an array of previous disciplinary experiences and interests, many were unable to understand the “drive-through” learning experience without an overarching integrated framework to guide their development.

In addition, the neuroscience program sought to cultivate an integrated awareness of the field through laboratory rotations, allowing graduate students to work extensively with various researchers to further interdisciplinary understanding. Laboratory rotations are a common practice in graduate science curricula, allowing students to experience different research topics before committing to a permanent advisor (Hall 2004). Yet the structure at ERU had additional cultural significance. Because of the lack of content knowledge provided through the formal curriculum, the rotations were an integral experience in allowing students to understand different disciplinary perspectives related to neuroscience. In addition, the practice allowed students to interact with faculty from multiple disciplinary backgrounds. The goal of the rotation practice was to provide students a first-hand understanding of the different epistemological and methodological approaches to brain function. Very few faculty supported the practice, however, and students were often uncertain of the significance of rotations. Several graduate students echoed the disciplinary biases of their faculty advisors, noting that the interdisciplinary rotations negatively impacted the pace of their overall development as scientists. Other faculty explained that little difference existed between the work of doctoral students in the interdisciplinary neuroscience program and peers from traditional disciplinary programs. Interdisciplinarity was not an active component of their daily research practice.

The formal curriculum lacked a sense of integration in regards to multiple bodies of knowledge related to the study of the brain. While the initial immersion in laboratory research encouraged students to identify an advisor and possible dissertation topic early in the program, such an experience frequently had a negative impact on a student’s interdisciplinary development. The laboratory remained the primary influence on the student experience, and very few of the laboratories at ERU were involved in broad, interdisciplinary efforts. Some value was found in the students’ close association with peers from other disciplines as part of a research laboratory. This arrangement highlights the overlap of knowledge that exists between neighboring fields of study. Certainly, a possibility existed for the laboratory experience to expose students to the interdisciplinary practice of neuroscience. Yet faculty seemed ambivalent as to a student’s enrollment in the interdisciplinary program. Interdisciplinarity was a tacit, implied practice, at best, for both students and faculty. The faculty exhibited little concern in regards to how best develop interdisciplinary scholars, and gave more attention to identifying those students with whom they wanted to work.

The goal of the ERU neuroscience program was to build “interdisciplinary research bridges” to expand the sites in which knowledge is produced and utilized. Such a position is well-suited to the changes which have occurred in the organization of research activities over the last two decades. Gibbons et al. (1994) noted that a multitude of links exist between these multiple sites, rendering disciplinary boundaries increasingly permeable. The findings from this study in part support the argument of Gibbons and his colleagues. In some ways, interdisciplinarity is an implied practice throughout the scientific disciplines. Students in the ERU program worked alongside peers from multiple disciplinary programs; the students and their advisors gave little thought to disciplinary affiliation, and concentrated on a shared research problem. These hybrid knowledge communities cannot be

adequately contained within the dichotomy that exists between disciplinary and interdisciplinary behavior. “Disciplinary boundaries are the result of history, vested interest, financing, entrepreneurial opportunity, or of academic coalitions,” concluded Gibbons et al. (p. 148); that is, the unique characteristics of knowledge do not in and of themselves create disciplinary boundaries. As the students and faculty of this program demonstrated, communities are frequently created based on shared interests, not strictly shared disciplinary affiliation.

The challenge for higher education is to provide training that enables students to realize the benefits of disciplinary affiliation, yet also develop interdisciplinary competencies. The findings presented in this article also demonstrate the continued strength of research laboratories in terms of graduate student training in the sciences. Particularly for students who had completed their first year in the program, their laboratory affiliation became the most crucial element of their graduate experience. Two reasons exist for the central role of the laboratory in the interdisciplinary curriculum. First, while the students were enrolled in an interdisciplinary program, the affiliated faculty members were largely bound by disciplinary membership. In terms of tenure, promotion, research funding, and advancement, faculty relied on their research laboratory and student assistants to produce knowledge of value. Second, students depended on their laboratory research to secure future employment. Students were able to reap the benefits of being associated with an innovative interdisciplinary area such as neuroscience, but were also able to demonstrate concrete knowledge of a specific area or topic. It was the latter upon which students most heavily relied when they sought employment in academia or industry. The research topic ensured students’ marketability, not necessarily their interdisciplinary doctoral degree. The glacial pace of change in higher education can be measured by the organization and administration of academic programs. While ERU supported an interdisciplinary curriculum in neuroscience, faculty and students defined their affiliation with a research laboratory in order to participate in the academic community. Areas of future research in regards to interdisciplinary education should consider the role of laboratory communities. In addition, the ability of graduates to demonstrate a range of research competencies over the course of their careers is significant.

I conclude by considering strategies to implement interdisciplinary graduate education. Table 1 identifies characteristics of an interdisciplinary curriculum for graduate education in contrast to the practices of the traditional disciplines.

Effective strategies to facilitate interdisciplinary learning in a graduate curriculum recognize the challenge of integration in regards to such programs. Several organizational elements worked in support of the neuroscience program at ERU: a full-time faculty director devoted to the program; external financial resources from the Office of the Provost; and a small, core group of dedicated faculty, most of whom taught in the first-year curriculum. Yet the program also demonstrated numerous weaknesses, such as the funding burden placed on the biology department and the lack of clear planning needed to foster an integrated, interdisciplinary experience. The curriculum did not require students to use content knowledge gained in one constituent discipline applied to another. Such weaknesses highlight the nature of the interdisciplinary curriculum as a social process, one that requires a clear content base and learning objectives.

The point here is not that disciplines are completely homogeneous cultures, but rather that disciplinary structures provide a shared, institutionalized framework to transmit values, beliefs, and norms valued by members. The question of whose knowledge, values, beliefs, and norms are to be prioritized for student learning—not simply the knowledge within one discipline, but across multiple disciplines, and in what way—is difficult for

Table 1 Comparison between disciplinary and interdisciplinary curricula in graduate education

	Traditional disciplinary curriculum	Interdisciplinary curriculum
Formal, written curriculum	Faculty with specialized training provide students with depth of knowledge in disciplinary field of inquiry	A range of faculty with diverse training provide students with breadth of integrated knowledge in interdisciplinary field of inquiry
Research	Students and faculty engage in research activity designed to further disciplinary understanding	Students and faculty engage in collaborative activities related to problems or topics that cut across disciplinary boundaries
Program administration	Programs exhibit institutional autonomy and bounded jurisdiction	Programs require collaborative support for faculty and students from across the institution
Institution	The university is a system of disparate, bounded, and autonomous disciplines engaged in knowledge production	The university is a network of collaborative and dependent efforts toward knowledge production

faculty in an interdisciplinary program to answer. It is not enough that the institution provides structural support or engages in rhetoric that supports collaborative knowledge. For practitioners of the disciplines, an interdisciplinary program transgresses the bounded cultural jurisdiction of academic communities. Even the seeming compromise of disciplinary autonomy in the interdisciplinary graduate curriculum at ERU resulted in tension. Disciplinary curricula are created in part by culture, knowledge, and interpretation shared among groups of individuals within a shared institutional space. Interdisciplinary curricula are formed largely through a similar process. Developing the interdisciplinary graduate curriculum not only requires overcoming disciplinary cultural fault lines that impede the integration of multiple cultures, but also understanding the inherent individual and institutional conflicts that accompany such efforts.

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