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Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Learning Activities

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Abstract

Interdisciplinary research collaborations (IDRC) are considered essential for addressing the most complex global community problems concerning science, health, education, energy, the environment, and society. In spite of technological advances, supportive funding, and even researcher proclivity to collaborate, these complex interdisciplinary research collaborations are often characterized as rife with conflict that can impede the collaborative processes and outcomes. When these collaborations falter or fail, junior scholars and scientists may be especially vulnerable. Research suggests that complex interactions of institutional, interpersonal, and individual factors can hinder or facilitate IDRC processes and outcomes. While early efforts focused on institutional and team factors, less is known about the individual-level factors or competencies needed for effective engagement in interdisciplinary research collaborations. Meanwhile, there is an escalating urgency to calls for institutions of higher education to provide relevant graduate education opportunities that enable young scholars and scientists to develop the competencies needed for effective interdisciplinary research.

This dissertation study investigated two specific questions, 1) what are the individual competencies critical for effective engagement in interdisciplinary research collaborations and 2) what specific learning experiences facilitate the development of those identified competencies during graduate school. This investigation identified 24 individual competencies and 471 developmental learning activities categorized in 18 distinct activity clusters. The results of this study can inform academic leaders interested in developing comprehensive graduate training programs that prepare emerging scholars for diverse careers requiring interdisciplinary research collaboration competence.

Chapter 1: Introduction

Statement of the Problem

Higher education has long been scrutinized for its relevance in preparing graduates to address real world problems (Anderson & Swazey, 1998; Brennan, 2007). Recently, the call for relevance has taken on a sense of urgency with regard to facilitating effective interdisciplinary research collaboration (IDRC) competencies in graduate students (Mitchell & Crittenden, 2000; Nash, 2008). Although interdisciplinary research collaborations are considered crucial for addressing the world's most complex challenges (Hesse, 2008; Hicks & Katz, 1996; National Academy of Sciences, 2004; National Institutes of Health, 2003), these collaborations nonetheless embody unique layers of complexity, frequently fail, are often characterized by negative conflict, and can even impede the career progress of new scholars (Golde & Gallagher, 1999; Kezar, 2005; National Academy of Science, 2004; Rhoten & Parker, 2004). While early studies of IDRC focused predominantly on institutional and logistical supports—e.g., shared space and technology enhancements—more recent studies identify a complex array of *contextual, interpersonal, and individual collaboration readiness factors* that interact to either hinder or enhance interdisciplinary research collaborations (Fiore & Schooler, 2004; Falk-Krzesinski et al., 2011; Klein, 2010; Hall, Stokols, et al., 2008).

These emerging studies build upon the earlier research emphasizing structural supports and additionally identify "soft skills" and team skills as critical for effective IDRC (Fiore, 2008; Rosas & Camarinha-Matos, 2008). Across the spectrum of readiness factors, however, those pertaining to *individual competencies* still remain the most illusive to articulate. In order for academic leaders to meet the challenge of providing graduate training that enhances interdisciplinary research collaboration, more must be understood about a) the individual

competencies (knowledge, skills, and attitudes) required for effective interdisciplinary research collaboration and b) specific learning activities that facilitate the development of those individual competencies.

Purpose of the Study

This study provides information about key career development and educational challenges that graduate students will face as they prepare for a variety of careers that will require them to participate in interdisciplinary research collaborations. This study also investigated the elements associated with interdisciplinary collaboration readiness with particular attention to the *individual readiness factors* and *knowledge, skills, and attitudes* deemed important. Finally, this study addressed gaps in the literature by identifying core individual competencies needed for effective interdisciplinary collaboration, as well as strategies and learning experiences that facilitate the development of those individual competencies. It is expected that the findings will inform graduate training efforts and can be applied to future qualitative and quantitative research.

Research Questions

This exploratory study investigated the following questions:

1. What are the *individual competencies* (knowledge, skills, and attitudes) needed for effective engagement in interdisciplinary research collaborations?
2. What specific *learning experiences* will help graduate students develop the identified competencies needed to effectively engage in interdisciplinary research collaboration?

Methods and Procedures

This investigation employed the Delphi research methodology to capture both qualitative and quantitative data collected from a group of experts recognized for their exemplary

achievements in IDRC. The Delphi research methodology was developed in the 1950s by Norman Dalkey of the RAND Corporation to gather expert judgment about military defense strategies (Dalkey & Helmer, 1963). It is now an accepted technique and has been employed in diverse studies spanning multiple disciplines (Skulmoski, Hartman, & Krahn, 2007; Zami & Lee, 2009). The Delphi scientific methodology is designed for research of complex problems or issues requiring the input of many subject matter experts and is particularly well-suited when the experts are from diverse backgrounds, do not have a history of communication with each other, and are remotely located from each other (Adler & Ziglio, 1996; Linstone & Turoff, 1975).

Though initiated as a traditional pen and paper survey method, web-based Delphi methods similar to those employed in a study by Colton (2002) and as described by Hatcher and Colton (2007) have been developed and were explored and modified for the purpose of this investigation. These more recent efforts employ methods of collaborative knowledge construction in highly structured virtual environments often with diverse and geographically dispersed subject matter experts (Barbera, 2006; Hatcher & Colton, 2007).

The Delphi technique is based on the premise that *collective intelligence* of non-collocated experts offered anonymously enhances the understanding of emerging issues and questions for which there is not yet common understanding, extensive published information, standard practice, or empirical research (Whitehead, 2007). The Delphi method involves structuring the iterative group communication and problem solving process so that the experts bring a collective intelligence to bear on the research questions posed. In this case, the questions were submitted to the group via electronic survey and focused on identifying and confirming *individual IDRC competencies and recommended graduate education learning activities for facilitating those competencies*. In response to predetermined research question prompts (see

Appendix E and F), experts contributed knowledge and information in the first round. After the responses were collected and reported back to the group, the experts again gave and received feedback about the collective responses in Round 2. This iterative process allowed for individual and group assessment of the emerging group view and adjustment of individual views and general group consensus relative to the question being studied (Linstone & Turoff, 1975). For this study, the first research question was addressed in Rounds 1 and 2, and the second research question was addressed in Round 3, with a final review in Round 4. The methodology is described in greater detail in Chapter 3.

Population

Scholars recognized for their exemplary achievements in interdisciplinary research collaboration and graduate education were selected to participate in this study. See Appendix A for sources of participants and Appendix B for certification.

Key Definitions

Interdisciplinary research. For the purpose of this study, a broad definition of interdisciplinary research proposed by Rhoten and Pfirman (2007) was adopted. The authors describe the concept as "the integration or synthesis of two or more disparate disciplines, bodies of knowledge, or modes of thinking to produce a meaning, explanation, or product that is more extensive and powerful than its constituent parts" (p. 58).

Competence. Building on Epstein and Hundert's (2002) conceptualization of competence as developmental, impermanent, and context-specific, the following definition of competence will be applied in this study: the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values, and reflections in daily practice. *Competencies* are further conceptualized as elements or components of competence

and consist of discrete *knowledge, skills, and attitudes* (Kaslow, 2004).

The above definitions are important in that they incorporate "attitudes" and thereby expand the discussion of competencies beyond strictly research-based skills and knowledge.

Limitations

There are many factors that contribute to the success or failure of interdisciplinary research collaborations, and often a combination of organizational, interpersonal, and individual elements interact in complex ways that determine the success or failure of the collaborative process (Hall, Stokols, et al., 2008). This investigation was not intended to be an exhaustive review of all of the possible permutations of collaboration influences but rather was focused narrowly on identifying those factors at the individual level that may be most useful for the development of graduate training activities to promote interdisciplinary research collaboration competencies. Organizational and structural factors were examined, as related to the objective of informing graduate training, in order to provide appropriate background context. Additionally, while this study does not result in a specific graduate training program, it does offer specific suggestions and best practices for graduate training as identified by key experts. Because this is a descriptive study, subsequent studies will be required to validate the application of the findings from this study.

Delimitations

Key experts included in this study were required to access a computer and connect to the Internet. Internet connectivity is standard for most research collaborations; however, the requirement here does preclude the inclusion of non-collocated, remote experts operating without Internet connectivity.

Summary

Ensuring that the next generation of scholars is properly prepared to engage in interdisciplinary research collaborations that address the most pressing global challenges has far-reaching consequences for the nation and for the world. In addition, attempts to identify individual competencies, as well as learning experiences that help graduate students develop them, is not a simple undertaking, particularly when those efforts require the consensus of a diverse group of scholars. Nonetheless, thanks to the quality and commitment of the experts involved in this study, the results have the potential to enhance graduate students' education and future careers, both with respect to individuals' personal and professional development and to the teams and diverse organizations that they will serve.

Chapter 2: Review of the Literature and Conceptual Framework

> Though the world does not change with a change of paradigm, the scientist afterward works in a different world... I am convinced that we must learn to make sense of statements that at least resemble these. What occurs during a scientific revolution is not fully reducible to a re-interpretation of individual and stable data. In the first place, the data are not unequivocally stable.
>
> Thomas Kuhn, The Structure of Scientific Revolution (1962)

Interdisciplinary Research Collaboration in Context

This chapter presents a comprehensive review of the literature relating to: a) the historical prevalence of interdisciplinary research collaboration; b) the recent paradigm shift and escalation of IDRC across virtually all disciplines; c) challenges, criticisms and cautions associated with defining and engaging in IDRC; d) emerging research on institutional, interpersonal, and individual factors that hinder or support interdisciplinary research collaboration readiness and outcomes; e) related issues for graduate training and career development; and f) social cognitive theoretical frameworks that provide the foundation for the investigation to identify required competencies and graduate education strategies to facilitate competence to engage effectively in interdisciplinary research collaboration.

Historical Prevalence of Interdisciplinary Research Collaboration

Throughout time, society's fascination with heroes has led to the creation of some of the most spectacular art, music, literature, and recounting of scientific discoveries and events in world history. In particular, many of the great scientific discoveries are often depicted in grand

stories of isolated endeavors undertaken by heroic individual scholars. Yet, quite often these exalted scientists and scholars themselves recall a different process of discovery that, if not characterized as collaborative, at least acknowledge the additive contributions of other scholars. The much-quoted phrase "standing on the shoulders of giants," frequently attributed to Isaac Newton, was actually first registered in 1159 and attributed to Bernard of Chartres when he acknowledged the contributions of the great Greek philosophers to then "modern thought" (McGarry, 1955, p. 167; Merton, 1965).

It is certainly true that new discoveries have not always been the products of the isolated endeavors that storytellers are so fond of portraying and that examples of world-changing interdisciplinary collaborations abound, including those noted by Brainard (2002) that resulted in the creation of the atomic bomb, the isolation of the structure of DNA, and the modern understanding of the movement of tectonic plates. Nonetheless, it is also true that in the past two decades there has been a rather dramatic increase in the interest, opportunity, expectation, and in some cases even the requirement for scholars *across virtually all disciplines* to participate in and show evidence of interdisciplinary research scholarship (Hicks & Katz, 1996; Jones, Wuchty, & Uzzi, 2008).

Paradigm Shift

Jacobs (2009) notes, "While calls for stronger interdisciplinary ties have a long history, in recent years the movement has had a strong wind behind its sails" (para. 2). A number of factors contribute to this escalation: the ever-increasing complexity of problems to be addressed (National Academies, 2004), the greater sophistication and availability of information networks and communication technologies supporting collaboration (Finholt, 2002; Olson et al., 2008), the apparent increased proclivity to engage in interdisciplinary research by emerging groups of

young scholars (Rhoten & Parker, 2004), the deliberate prioritization by funding agents who require evidence of IDRC (e.g., National Institutes of Health, http://commonfund.nih.gov/interdisciplinary/), and the subsequent pressure on academic leaders to engage in cutting edge research and to compete for those restricted funds (Rijnsoever & Hessels, 2011).

Interdisciplinary Research Collaboration: Critical Needs

Many scholars support the shift toward more collaboration as necessary for addressing the world's most pressing social, health, and environmental problems. Mabry, Olster, Morgan, and Abrams (2008) assert:

> The sciences concerned with optimal health, well-being, and disease management have revealed just how broad the future world view needs to be. At the end of the day, the simple, single-cause, single-discipline, and now, even single-level-of-analysis models—whether predominantly biomedical or predominantly behavioral or social-ecologic—are increasingly viewed as necessary but insufficient. (p. S223)

Not surprisingly, calls for IDRC have extended well beyond the medical and scientific fields, and interdisciplinary research collaboration is discussed as becoming increasingly important for addressing a broad range of global problems, including terrorism and security (Popp et al., 2004), economic renewal, engineering, and innovation, as well as for inspiring creativity in the arts and humanities (Crane & Chiles, 2011).

Defining Interdisciplinary Research

Nonetheless, systematic efforts to better understand the processes of interdisciplinary collaboration are relatively new. A common concern expressed in the early literature was for the need to clarify what is meant by interdisciplinary research and, as importantly, to devise valid

and reliable ways of evaluating its impact and effectiveness (Fuqua, Stokols, Gress, Phillips, & Harvey, 2004; Rosenfield, 1992). Interdisciplinarity was, and in many ways remains, a popular buzzword, becoming, as some suggest, a "catch all" term that jeopardizes empirical efforts to devise measurable ways to support and facilitate both interdisciplinary skill development and collaborative outcomes (Klein, 2008).

Although research is still lagging regarding ways to facilitate and evaluate IDRC, progress has been made toward operationally defining what is meant by interdisciplinarity. These efforts have resulted in the following basic research orientation distinctions to be adopted in this investigation; they were first drafted by Rosenfield (1992) and later endorsed by Stokols, Hall, et al., (2008):

> Unidisciplinarity: Process in which researchers from a single discipline work together to address a common problem.
>
> Multidisciplinarity: Sequential process, researchers in different disciplines work independently, with a goal of eventually combining efforts to address a common research problem.
>
> Interdisciplinarity: Interactive process wherein researchers work jointly, each drawing from unique, discipline-specific perspective to address a common research problem.
>
> Transdisciplinarity: Integrative process, researchers work jointly to develop and use a shared conceptual framework that synthesizes and extends theories, concepts, and methods to create new models and language to address common research problem. (p. S79)

For the purposes of this investigation, it is important that interdisciplinary *research* be distinguished from common understandings of interdisciplinary *education*. Interdisciplinary

education typically refers to programs of study, usually at the undergraduate level, whereby the curriculum is designed to provide students with broad-based educational classes and experiences. Many first-year experiences set as a goal the effort to expose students to a general view of various disciplines, commonly referred to as interdisciplinary education.

It is also important to distinguish interdisciplinary research collaboration from disciplinary collaboration. Interdisciplinary collaboration is a form of collaboration, but not all collaborations are interdisciplinary, and those that are have rather particular dimensions that will be discussed in detail.

Research Examining Trend or True Shift

In spite of the clarity provided by these general definitional terms, and regardless of the elevated and even passionate discussions of IDRC, some critics suggest that limited empirical evidence exists to support the claim that there has actually been a fundamental change in relation to IDRC in the broader University-based system (Shinn, 1999; Weingart, 1997). Rhoten (2003) investigated the question of whether the perceived shift toward IDRC reflected a trend or true transition. Using a multi-method analysis of the social and technical conditions for interdisciplinary collaboration, she reviewed interdisciplinary research centers and programs and found that what are often deemed interdisciplinary are merely "traditional modes of work patched together under a new label" (Rhoten, 2004, p. 6). Additionally, Rhoten concluded that interdisciplinarity did not typically suffer from "a lack of extrinsic attention at the 'top' or intrinsic motivation at the 'bottom,' but rather, from a lack of systemic implementation in the 'middle'" (p. 6). Her initial analysis, extended by Rhoten and Parker (2004) and Rhoten and Pfirman (2007), suggested that universities approached IDRC as a trend and not a real undertaking, and as a result, their interdisciplinary efforts are conducted in "piecemeal,

incoherent, catch-as-catch-can fashion rather than approaching them as comprehensive, root-and-branch reforms" (Rhoten, 2004, p.6.) For emerging scholars, this has significant, and potentially devastating, educational and career development consequences (Gaff, 2002).

In a subsequent investigation to examine the question of trend or true transition, Wuchty, Jones, and Uzzi (2007) conducted a comprehensive review of 19.9 million papers over five decades and 2.1 million patents. Their research clearly showed that teams increasingly dominate solo authors in the production of new knowledge across nearly all fields, that this measurable trend began decades ago, and that it has escalated significantly in the past two. Jones et al. (2008) support the findings that scholarly collaborations and joint publications are increasing across virtually all fields of science, engineering, and social science and further conclude that elite universities are playing a more dominant role in the shift in knowledge production.

Although Rhoten's conclusions may at first appear to be at odds with those of Wuchty and Jones, in fact both may be accurate. IDRC is increasingly responsible for new knowledge production, and at the same time, universities lag behind in establishing systematic ways of defining, supporting, and/or measuring IDRC. For emerging and established researchers, this gap can have tremendous consequences.

Challenges

Joint collaborations and publications increasingly generate novel discoveries and knowledge that are commonly touted as evidence of a new research paradigm. In spite of the proliferation of successful collaborations, some scholars caution that collaboration itself is not the goal, but rather the means, and that the goals should dictate the process of discovery adopted. In this regard, Toomela (2007) distinguishes between elaborative knowledge and emergent knowledge and identifies when collaboration may be most beneficial, as well as when types of

collaborative efforts may in fact hinder or prevent the construction of emergent knowledge (p. 198). Metz (2001) cautions that there is a difference between interdisciplinary *conversation* and interdisciplinary *research* and offers that she has "seen too much that exhibits a drop in quality rather than an increase in complex work" (p.17). That IDRC is both popular and important, she cautions, does not make it accessible (p. 17).

Cautions

IDRC advocates are further cautioned to recognize that the strength of IDRC efforts remain in the strength of the individual disciplines whose diverse perspectives are brought together to address a problem. Reis (2000) quoted noted Nobel laureate and physicist Steven Chu: "Our strength and our weakness is the department structure. The department is the guardian of its field. It trains students and promotes intellectual excellence. But the departmental structure means that we must carve up all intellectual pursuits into quasi well-defined segments" (Reis, 2000).

Hansen (2009) supports the notion of strategic collaborations and suggests that in the context of the global environment, the concept of the "t-shaped leaders" will be the key to cultivating the future of work, whereas individuals are able to show vertical depth *and* contribute effectively across other disciplines. Leaders, according to Hansen, will need to inspire vigorous, constructive debate and conflict and will need to seek diversity in council but establish unity in execution. In many cases, doing so will require dramatic changes in research and operational cultures.

Still another group of researchers acknowledge research paradigm changes but question whether enthusiasm and pressure have supported avoidance regarding the hardships and individual stresses these shifts have created (Hicks & Katz, 1996; Ziman, 1994). Ambiguous

metrics mask a failure rate for University-based collaborations estimated to be close to 50% (Kezar, 2005). When collaborations, particularly IDR collaborations, succeed, the results are impressive, though the process is not always smooth nor without significant challenges. Yet, when they fail, which is almost as often, there can be serious consequences to the institutions, teams, and individuals involved.

Career-Related Issues

Rhoten and Pfirman (2007) found that scholars working in interdisciplinary areas still remain affiliated with discipline-specific departments, and many times, colleagues in the departments can be indifferent if not antagonistic to research conducted outside the narrow field. As Curtin (2008) points out, we revel in IDRC talk, but tenure and promotion committees do not review groups, they review individuals, and often those metrics have not been sufficiently updated.

The personal impact to the individual's career development and career progression can be significant for scholars engaged in interdisciplinary research, and studies are just beginning to identify in exactly what ways. While there does seem to be some recognition of the need to reframe the university review structure, it nonetheless seems entrenched in a traditional framework that recognizes and rewards discipline-bound scholarship but has yet to establish clear metrics for rewarding IDRC. Peer review, journal publication, and tenure and promotion considerations are shown to be affected, and not always favorably, by engagement in IDR (Brainard, 2002). Rijnsoever and Hessels (2011) investigated the characteristics of researchers engaged in disciplinary and interdisciplinary research and looked at which collaborations were most rewarded in different disciplines, as well as which collaborations contributed more to career progress. They found that females participated more in IDRC and that for both genders, years of

research experience were positively correlated with IDRC. Interestingly, work experience in firms or governmental institutions increased the "propensity" for interdisciplinary collaboration but *not* disciplinary collaborations. Most notably, they concluded that while disciplinary collaborations were positively associated with career progression, interdisciplinary collaborations were not (p. 463). De Boer (2006) also documented that (disciplinary) reward structures are often mentioned as the main barrier for inter- and transdisciplinary research.

Emerging Research Field: "Science of Team Science"

In the past, efforts to understand IDRC processes and methodologies have been criticized for being predominantly framed from traditional, discipline-specific, and even anecdotal perspectives quite lacking in integrated, empirical support. Early studies exemplify the diversity of thought and complexities of analysis associated with understanding interdisciplinary collaborations and as a result, offer somewhat fragmented understandings. As Klein (2009, p. 23) points out, collaboration is not synonymous with interdisciplinarity, and early attempts to apply disciplinary collaboration and strict team collaboration research fell short when considered in the context of IDRC.

In response, a group of scholars initiated formal recognition of an emerging field of research, the science of team science, to conduct and integrate research concerning the complex factors that hinder or enhance interdisciplinary collaboration and to develop ways to measure and evaluate methods and outcomes (Stokols et al., 2003). Having prioritized IDRC, several major funding agencies support the research efforts of this diverse community of scholar-contributors, and although significant gaps remain to be investigated, these interdisciplinary research teams have identified certain patterns and themes that shed light on a complex and interacting array of specific *institutional, interpersonal,* and *individual* collaboration readiness factors. Sclater and

Bolander (2004) cautions that the factors should not be viewed in isolation and that there is a need to "foreground the most significant factors" (p. 198). As the current study focuses on graduate education and identifying malleable competencies and strategies for developing those competencies at the individual level, individual collaboration readiness factors will be highlighted here with a brief discussion of institutional and interpersonal factors.

Collaboration Readiness: Organizational and Structural Factors

While it is true that interest, support, and pressure for interdisciplinary collaboration have escalated in recent years, implementing interdisciplinary practices and clear-cut strategies for facilitating IDRC has proven much more difficult, as is reflected in its consistently high failure rate (Kezar, 2005). Additionally, experience does not always support proclivity or practice, as evidenced by research showing that junior colleagues with less IDRC experience rate collaboration more optimistically than more experienced senior researchers, who tend to rate interdisciplinary collaboration processes more unfavorably (Hall, Feng, et al., 2008; Hall, Stokols, et al., 2008; Hansen, 2009; Kezar, 2005). These discrepancies inspired the investigators to explore whether junior colleagues tended toward unwarranted optimism and whether the senior researchers were grounded in a more troubled, and possibly realistic, view of interdisciplinary collaboration. As a result, initial efforts to facilitate and enhance IDRC were geared primarily toward addressing the more obvious structural and institutional elements, such as physical space and proximity of team member offices and laboratories, administrative support, research funding, and communications and technological enhancements. This is not to suggest that these institutional elements were easy to address. They were, however, initially easier to identify than the more illusive interpersonal and intrapersonal factors that also interact in complex ways to hinder or enhance IDRC and that have become the focus of recent efforts.

Initial efforts to address organizational and environmental collaboration readiness factors seemed particularly well-placed, as early research indicated that the most frequently reported hindrance to interdisciplinary collaboration was the work environment, whereas the most frequently reported facilitator was the extent to which faculty *value* interdisciplinary collaboration, the latter being more difficult to decipher (Mellin & Winton, 2003). Just as Rhoten's (2003) analysis indicated the need for administrative prioritization, Rijnsoever and Hessels's (2011) study of interdisciplinary versus disciplinary collaboration and their career-related effects offered critical policy recommendations for academic leaders seeking to bolster IDRC. These recommendations included not just providing funding support and recruiting talent with interdisciplinary interests but also changing the evaluation and reward processes, which still heavily favor discipline-specific scholarship (p. 470).

In the spring of 2011, a group of interdisciplinary scholars and academic leaders convened to discuss issues related to "Facilitating interdisciplinary research and education" (University of Colorado-Boulder, FIRE Symposium, 2011). Throughout the conference proceedings, the group identified and discussed several common organizational/environmental strategies developed by academic leadership and believed to be moderately effective in facilitating IDRC, including: providing premium interdisciplinary collaboration space, in some cases separate state-of-the-art buildings, redesigning break rooms and faculty lounges to inspire informal interactions and organic collaborations, mentoring programs, site visits, shared readings, faculty training and retreats, policy workshops, case conferences, and even technological support and training to enhance virtual communications to supplement face-to-face meetings.

There was general agreement that structural supports were essential but alone fell short of addressing the major complexities of IDRC. Several challenges were identified. Issues arose surrounding who owned collaborative, often premium, space and therefore who paid for it, and budgetary allocations and administrative support decisions were often cited as being rife with conflict. Concerns were expressed that over time, the expensive centers of interdisciplinary excellence lose their innovative benefits and revert to a different kind of disciplinary silo; stagnation was a common concern, as were problems associated with locating faculty out of their departments into the centers and then having to reintegrate them if the collaborations falter or fail. During the conference proceedings, cluster hiring was cited as creating some opportunities but also as many challenges relative to rewards and evaluations. Institutional policy and the pervasive higher education culture regarding tenure and promotion were still considered and, many argued, should remain heavily biased toward disciplinary work. Finally, there was a clear sense from the group that the reward structures, if they existed at all for IDRC, needed to be carefully evaluated in light of interdisciplinary participation (FIRE Symposium, Day Two).

The extent to which context-specific institutional collaboration readiness factors are properly attended to can be a critical determinant of collaboration capacity and ultimate outcome success (Metzger & Zare, 1999; Porter, Roessner, Cohen, & Perreault, 2006), but institutional readiness factors alone, in spite of extensive support and restructuring, are not sufficient and must be considered within the broader context of interacting team and individual factors. Collaboration conflict and communication issues were cited as separate from and no less important than matters of structure (Bennett, Gadlin, & Levine-Finley, 2010). For graduate students in particular, upper-level structural considerations may seem far removed and may in

fact be issues over which they have little control. Nonetheless, they present important challenges of which emerging scholars need to be aware particularly as they influence teams and training.

Interpersonal and Team Collaboration Readiness

Early studies of teams focused predominantly on within-discipline collaborations and often illuminated task-specific issues related to coordination (Dyer, 1984). In later decades, a proliferation of team studies investigated more complex patterns of team-oriented conflict and communication challenges and underscored input-process-output (IPO) frameworks (Salas, Stagl, & Burke, 2004). Additional studies offered an important foundation for understanding interdisciplinary research teams in academia and explored issues beyond those of a task-specific nature, including interpersonal communications and relationship-building skills and team structure, dynamics, and training (Blackburn & Lawrence, 1995; Bolman & Deal, 1997; Gist, Stevens, & Bavetta,1991). More recently, team studies have begun to differentiate between "team-building" exercises and activities, which merely show short-term "feel-good" gains and only modest results relative to collaborative output, and more substantive "team-training" efforts, which show more pronounced results-oriented effects (Salas, 2011).

Fiore and Bedwell (2011) caution that team training needs to include both task and teamwork training involving communication and relationship-building skills. They suggest that "we are producing highly task competent scientists, but not necessarily team-competent individuals. Nonetheless, we are still expecting them to function in a team" (2011, n.p.). This is especially critical and challenging in light of distinctions being drawn between disciplinary team cooperation and interdisciplinary team collaboration and is reflected in the literature (Amey & Brown, 2004; Nash, 2008). While many early team studies focus on promoting cooperation,

which is recognized by IDRC researchers as necessary for collaboration, interdisciplinary collaboration is further distinguished as a "special case of positive interdependence" (Tjosvold, 1986, as cited by Amey & Brown, 2000, p. 4) requiring integrated thinking where new knowledge is created from the merging of interdisciplinary perspectives.

In one of the earlier studies of interdisciplinary teams, Mariano (1989) identified goal and role conflict, decision-making, and interpersonal communication as the three most critical elements that hindered or promoted interdisciplinary activities. Role ambiguity, overlapping competencies, and preconceived notions of one's own and other disciplines were identified as frequent sources of role conflict (p. 286). Additionally, a lack of clear goals or consensus about decision-making led to fragmentation, and communication issues relating to giving and receiving feedback were noted as needing particular attention with the interdisciplinary teams (Mariano, 1989).

A decade later, Younglove-Webb, Gray, Abdalla, and Thurow (1999) investigated interdisciplinary teams specifically in academia and found that the difficulties experienced by collaborative teams were exacerbated when researchers spanned multiple disciplines. The study found that the interdisciplinary teams needed more time at the outset of the collaboration for orientation or modest team-building and that throughout the collaborations, the teams struggled with an array of *substantive* differences, uniquely related to discipline-specific knowledge and methodological orientation and establishing accountability norms and communication and conflict negotiation strategies (p. 10). In the interdisciplinary groups studied, productivity was negatively affected and delayed, and negative feelings developed as a consequence of several factors: some collaborators were not collocated, other collaborators attempted to influence the

direction of the research, and competing disciplinary responsibilities conflicted with the team projects (Younglove-Webb et al., 1999).

Subsequent studies of interdisciplinary teams began to unveil many of the same issues that previous team studies illuminated; however, the emerging literature showed that the apparent "substantive differences" highlighted by Mariano and Younglove-Webb warranted additional investigation. Interdisciplinary teams embodied unique layers of complexity, and previous team studies, while helpful, left many unanswered questions. Marking what many consider the beginning of a more comprehensive level of analysis of interdisciplinary research collaboration readiness, Stokols et al. (2003) created a conceptual model of transdisciplinary scientific collaboration readiness based on studies of research centers in the field of tobacco science. While acknowledging previous findings by Rhoten (2003) that "groupthink" occurs among too similar collaborators, the data collected by Stokols et al. further indicated that "when investigators with widely different disciplinary backgrounds and spatially separate offices and laboratories undertake collaborative projects, the potential for group fragmentation and polarization is strong" (p. 212), so much so that a major challenge is striking a balance between the *diversity and debate* that IDRC requires for innovation and the *intellectual integration and social support* needed for a team to effectively reach its goals.

With the emergence of team science studies, efforts have increased to understand the broader array of institutional, interpersonal, and intrapersonal conditions well beyond those of task-restricted earlier studies. Rosas and Camarinha-Matos (2008) suggest that in addition to the "hard" factors determining collaboration readiness, several other "soft" factors, including character, willingness, and affectivity/empathy, need to be considered. In *Collaboration and Team Science: A Field Guide*, Bennett et al. (2010) offer a variety of practical suggestions for

building effective teams and enhancing collaboration. Among the many critical issues identified are: fostering trust, developing a shared vision, communicating about science, sharing credit, and handling conflicts. Likewise, Peters and Manz (2007) investigated antecedents of virtual team collaboration and concluded that depths of relationships, trust, and a shared understanding need to be in place for a high level of collaboration to occur.

The existing research provides a compelling picture for antecedent team conditions necessary for IDRC. Still, the difficulty persists in understanding how to create the interpersonal conditions for those factors to develop/thrive and what antecedent factors at the individual level complicate or enhance collaborative interactions. Katz and Martin (1997) state that "collaboration is an intrinsically social process and, as with any form of human interaction, there may be at least as many contributing factors as there are individuals involved.... At the most basic level, it is people who collaborate, not institutions" (pp. 4, 9). Williams (2002) acknowledges the predominance of research aimed at the institutional and organizational level and challenges that "little attention is accorded to the pivotal role of individual actors" (p. 103). Attempts to unpack the intrapersonal factors are quite varied and somewhat ambiguously framed and often lack rigorous, empirical merit. Yet, the root of teamwork exists at the individual level, and in light of the fact that individuals—not teams—are granted tenure, it is hardly surprising that the most recent efforts to understand components of effective interdisciplinary collaboration have begun to focus on the individual and intrapersonal dimensions of readiness.

Individual Collaboration Readiness

Efforts to investigate organizational and team collaboration readiness factors, though not exhaustive, have certainly yielded important insights and offer practical guidelines for academic leaders seeking to understand the structural and interpersonal conditions necessary to support

collaborative processes and outcomes. Meanwhile, there have been fewer efforts to understand individual and intrapersonal collaboration readiness factors and competencies, and those that exist yield results that are more illusive and difficult to translate to practice. Despite being considered the most complex to describe, however, many scholars consider individual level factors to be the most fundamental building blocks for effective collaboration (Amey & Brown, 2000; Mattessich & Monsey, 1992).

Compounding the difficulties in identifying intrapersonal collaboration readiness factors is the fact that though it may be simpler to segregate collaboration readiness factors into three distinct domains—organizational, interpersonal, or individual—it is commonly understood that these various elements interact in complex ways within the unique context of the collaboration. Viewing each in isolation from the others provides an inadequate picture for understanding collaboration dynamics. Williams (2002) conducted a review of the literature and attempted to investigate both institutional and relational factors that support "competent boundary spanners" while focusing on the individual actors within interdisciplinary collaborations (p. 121). Williams's investigation identified competency-based variables and factors including:

> the boundary spanner as network manager; the importance of building effective personal relationships with a wide range of other actors; the ability to manage in non-hierarchical decision environments through negotiation and brokering; and performing the role of "policy entrepreneur" to connect problems to solutions, and mobilize resources and effort in the search for successful outcomes. (p. 121)

In a separate conceptualization of the interacting dimensions of collaboration readiness, Stokols (2008) and his colleagues offer that intrapersonal collaboration readiness of emerging scholars can be:

> gauged in terms of their preparedness for the uncertainties and complexities of transdisciplinary teamwork, their methodologic flexibility, their openness to disparate disciplinary perspectives and world views, and their willingness to devote substantial amounts of time both to learning about others' expertise and developing intellectual and personal relationships. (Stokols, Misra, et al., 2008, p. S106)

Additionally, Stokols, Misra, et al. suggest, "Individuals who value collaboration, support a culture of sharing, and embrace a transdisciplinary ethic are well-suited for transdisciplinary teams" (2008, p. S106). These preliminary descriptions of collaboration readiness provide a critical first step toward identifying general intrapersonal factors. Yet, as the researchers acknowledge, these broad descriptions lack a degree of specificity that translates easily to trainee program interventions.

Novel contributions to the emerging literature that bridge understandings of interpersonal and intrapersonal collaboration readiness come from scholars investigating the ways in which philosophical differences and diverse worldviews affect interdisciplinary collaborations. With roots in philosophy and cross-cultural studies, these scholars look at the impact of discipline-specific methods and processes and how these influence interdisciplinary communication (Eigenbrode et al., 2007; Reich & Reich, 2006). They assert that communicating and collaborating across discipline boundary lines is similar to communicating with those from other less familiar cultures (Becher, 1989).

This is particularly relevant in regard to many institutions' stated goals to develop interdisciplinary research cultures. Silver (2003) maintains that institutions do not have a culture but rather are made up many subcultures, and attempts to build a culture of interdisciplinary research collaboration must necessarily consider what that means across disciplines. Typically,

scholars are drawn to particular disciplines as they seek out like-minded thinking and problem-solving approaches (Crowley, Eigenbrode, O'Rourke, & Wulfhorst, 2010). When differences come to light in interpersonal interactions, sometimes with highly political undertones, they stem from factors that exist on a very personal individual level and reflect deep-seated values and preferences, many of which the individual scholar may never have reflected upon and may not even be aware of until he or she comes into conflict in the context of a research collaboration (O'Rourke & Crowley, 2011).

In their review of interdisciplinary education and teamwork, Hall and Weaver (2001) suggest that individuals find it "more comfortable to remain within one's own discipline where communication is facilitated by specialized vocabulary, similar approaches to problem solving, common interests and understanding of issues" (p. 867) and that the individual's view of the world and theoretical basis for problem solving is shaped and further reinforced by his or her discipline of choice and through socialization via educational experiences. Citing early work conducted by Petrie (1976), Hall and Weaver (2001) develop the notion of individual cognitive maps wherein the individual becomes immersed in the cognitive and perceptual approach embraced by the discipline and becomes entrenched through repeated use and communication at the individual level. Reinforcing the notion of disciplines as separate tribes or cultures, Petrie cautions, "quite literally, two opposing disciplinarians can look at the same thing and not see the same thing" (cited by Hall & Weaver, 2001, p. 867). Still, the choice of one's home discipline is quite personal. Hall and Weaver suggest that emerging scholars be provided interdisciplinary education that addresses role blurring, group skills, communication skills, and conflict resolutions. Nonetheless, many of the questions about precisely *how* to promote effective collaboration remain unanswered.

Individual Competencies

Not surprisingly, many of the advances in our understanding of those collaborative conditions and competencies needed for effective interdisciplinary research come from research in the medical profession, where IDRC has a vibrant yet complicated history. In their investigation of interdisciplinary research training in a school of nursing, Larson, Cohen, Gebbie, Clock, and Saiman (2011) caution that although interdisciplinarity has become a favored model of scholarly inquiry, "the assumption that interdisciplinary work is intuitive and can be performed without training is short-sighted" (p. 29), and collaboration challenges based on disparate values, knowledge bases, and approaches to inquiry lead to a tendency for graduate students and mentors to retreat back to their safer disciplinary frameworks. But, if training is to be offered, the question remains, what are the goals of the training efforts and what are the key competencies—i.e., the knowledge, skills, and attitudes—that would be most important to facilitate? When the goal is to develop appropriate graduate student training opportunities, then the necessary starting place must be first identifying and delineating the foundational and core competencies associated with interdisciplinary collaboration.

Defining Competencies

A review of the literature shows an escalating interest in competency-based education across many professions in an effort to define core competencies and to provide guidelines for innovative approaches to training at specific developmental career stages that can be followed with assessment (Kaslow, 2004). In 2005, the Organisation for Economic Co-operation and Development (OECD) published the results of a considerable international effort to establish a framework for the key competencies individuals would need for a successful life and well-functioning society, concluding:

> Many scholars and experts agree that coping with today's challenges calls for better development of individuals' abilities to tackle complex mental tasks, going well beyond the basic reproduction of accumulated knowledge. Key competencies involve a mobilisation of cognitive and practical skills, creative abilities and other psychosocial resources such as attitudes, motivation and values. (p. 8)

Diverse scholars involved in similar efforts to develop competency-based training programs readily acknowledge that modern challenges require that serious attention be paid to competencies beyond knowledge and skills and recommend first addressing the variability in definitions of competencies and competence before tackling how soft skills and psychosocial resources such as attitudes, motivation, and values can be addressed in training (Kaslow, 2004).

Epstein and Hundert (2002) provide a conceptualization for defining and assessing professional competencies for physicians and trainees that has been cited as appropriate for other health professionals and practitioners, scholars, and scientists. They propose that professional competence is "the habitual and judicious use of communication, knowledge, technical skills, clinical reasoning, emotions, values, and reflection in daily practice" and is built "on a foundation of basic clinical skills, scientific knowledge, and moral development," including cognitive, integrative, and relational functions (p. 226-227). Widely cited in emerging research on interdisciplinary health research and training, Epstein and Hundert's conceptualization proposes that competence depends on habits of mind, including attentiveness, critical curiosity, self-awareness, and presence and that professional competence is "developmental, impermanent, and context-dependent" (p. 227). Their conceptualization is consistent with Stratford's (1994) proposal of competencies as observable, measurable, containable, practical, derived by experts, and flexible.

Kaslow (2004) expanded the conceptualization of competencies beyond narrow skills and knowledge and articulated a framework of competencies as elements or components of competence consisting of discrete knowledge, skills, and *attitudes*, thereby giving attention to the more ambiguous attitudinal elements previously left unaddressed. Building on this framework, scholars have attempted to identify and define with greater clarity the constellation of knowledge, skills, and attitudes needed for effective interdisciplinary research (Gebbie et al., 2008; Larson, Cohen, et al., 2011; Larson, Landers, & Begg, 2011; Mitchell & Weiler, 2011).

Although most attention was still on the relatively familiar "hard skills" associated with research, Gebbie et al. (2008) offered the most detailed, expert-informed list of 17 individual competencies necessary for interdisciplinary research. The competencies fall into three main categories: research, communication, and engagement. These competencies provided the foundational starting point for the current investigation and for the Round 1 questionnaire.

According to Gebbie et al. (2008), the scholar who has completed doctoral work should be able to:

Conduct research

- Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks
- Integrate concepts and methods from multiple disciplines in designing interdisciplinary research protocols
- Investigate hypotheses through interdisciplinary research
- Draft funding proposals for interdisciplinary research programs in partnership with scholars from other disciplines

- Disseminate interdisciplinary research results both within and outside his or her discipline

Communicate

- Advocate interdisciplinary research in developing initiatives within a substantive area of study
- Express respect for the perspectives of other disciplines
- Read journals outside his or her discipline
- Communicate regularly with scholars from multiple disciplines
- Share research from his or her discipline in language meaningful to an interdisciplinary team
- Modify his or her own work or research agenda as a result of interactions with colleagues from fields other than his or her own
- Present interdisciplinary research at venues representing more than one discipline

Interact with others

- Engage colleagues from other disciplines to gain their perspectives on research problems
- Interact in training exercises with scholars from other disciplines
- Attend scholarly presentations by members of other disciplines
- Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks

- Author publications with scholars from other disciplines (Gebbie et al., 2008, p. 69)

Designed to address Center-based research competencies, the study conducted by Gebbie et al. (2008) comprises one of the most detailed attempts to gather expert opinions about interdisciplinary research competencies documented. Gebbie's study deviates from the current investigation in two important ways. Gebbie and her colleagues focused on defining competencies specifically for interdisciplinary health trainees engaged in research centers. From the identified competencies, they created and evaluated a didactic course to prepare interdisciplinary scholars and faculty based on their own educated assumptions of how those competencies might be facilitated (Gebbie et al., 2008; Larson, Cohen, et al., 2011; Larson, Landers, et al., 2011). The current investigation will build on Gebbie's competency framework and will further explore *expert-proposed* learning experiences recommended to facilitate those competencies. It is expected that while scholars may suggest a comprehensive course as a learning option, they may also identify additional discrete and limited learning experiences.

Theoretical Foundation: Social-Cognitive Theory and Social-Cognitive Career Theory (SCCT)

Research in the field of interdisciplinary team science suggests collaboration practice and training are affected by the specific context of the collaboration and by complex interactions between team members each operating from a unique set of intrapersonal factors (Nash, 2008; Stokols, Hall, et al., 2008; Stokols, Misra, et al., 2008). Two theoretical frameworks support the conceptualization of interdisciplinary research collaboration as a process of emergent interactive agency: social cognitive theory and social cognitive career theory. These theories have inspired

substantial research across multiple disciplines, and each is briefly framed here with respect to graduate student career development and training.

Social Cognitive Theory: Albert Bandura

Bandura (1986) introduced a novel way of conceptualizing social foundations of thoughts and action called the social cognitive theory, whereby individuals are:

> neither autonomous agents nor simply mechanical conveyers of animating environmental influences. Rather, they make causal contribution to their own motivation and action within a system of triadic reciprocal causation. In this model of reciprocal causation, action, cognitive, affective, and other personal factors, and environmental events all operate as interacting determinants. Any account of the determinants of human action must, therefore, include self-generated influences as a contributing factor. (Bandura, 1986, p.1176)

Social cognitive theory frames human development, adaptation, and change from three distinct but interacting modes of agency: personal agency, proxy agency, and collective agency. Bandura (2002) considered successful functioning as requiring a blend of all three of these modes of agency: individual agency that is direct and personal, collective agency that is exercised through group action, and proxy agency that requires others to act on one's behalf (p. 270). According to Bandura, the most central element of human agency is personal efficacy beliefs, which he defined as "people's judgments of their capabilities to organize and execute courses of action required to attain designated types of performances" (1986, p. 391). Regardless of cultural variations of agentic patterns, Bandura considered successful functioning in any culture to require a blend of these different modes, with beliefs of personal efficacy being most central (Bandura, 1997, 2002).

Especially relevant to the discussion of competency-based education, Bandura felt that self-efficacy beliefs are dynamic and domain-specific. According to Bandura:

> Self-efficacy beliefs regulate human functioning through cognitive, motivational, affective, and decisional processes. They affect whether individuals think in self-enhancing or self-debilitating ways; how well they motivate themselves and persevere in the face of difficulties; the quality of their emotional life; and the choices they make at important decisional points which set the course of life paths. (Bandura, 2002, p.271)

Bandura (1986) framed four primary sources of self-efficacy beliefs, each having particular relevance to issues of training and development, including: 1) personal performance accomplishments, 2) vicarious learning, 3) social persuasion, and 4) physiological states and reactions.

Of these sources of self-efficacy, personal performance success experiences have the greatest influence on positive self-efficacy belief development, and personal performance failures, conversely, can also foster weaker or more negative domain-specific beliefs (Niles & Harris-Bowelsby, 2005, p. 88). This is particularly relevant in the discussion of early career experiences that may set the stage for individual efficacy beliefs, either positive or negative, toward interdisciplinary research collaboration. Additionally, the career development relevance of Bandura's work can be seen not only in the most critical issues relating to personal self-efficacy, but also with respect to the collective efficacy associated with group and interdisciplinary collaboration.

Relative to the current investigation to inform the understanding of interdisciplinary research collaboration competencies and training, it is important to note how a group operates through the member behaviors. While individuals make up the social system of a collaborative

group, the group's collective efficacy is not an additive function of the individual efficacy beliefs but is, rather, an emergent entity that evolves as part of the group process (Bandura, 2002, p. 271). A number of large-scale, meta-analysis research projects employing a broad spectrum of methodologies conducted over the years provide empirical support that perceived self-efficacy enhances individual functioning just as collective efficacy has been shown to enhance group functioning (Boyer et al., 2000; Holden, 1991; Stajkovic & Lee, 2001).

As with other educational and career-related experiences, early experiences with collaboration can either enhance or hinder collaboration efficacy at both the individual and collective level. These in turn have an impact, either positive or negative, on outcome expectations going forward. Outcome expectations are a critical element of Bandura's model and are quite simply defined as beliefs about what will happen as a result of performing specific actions, e.g., Will I be able to contribute to the group collaboration and will that work result in something I value? Although Bandura (1997) and later career theorists (Lent, Brown, & Hackett, 1996, p. 381) consider outcome beliefs less influential than self-efficacy beliefs, they and other scholars still consider the influence of both along with contextual factors. For graduate training considerations, it becomes critical to assess how self-efficacy beliefs and outcome expectations influence career and educational goals, individual and group behavior, and persistence to success.

Social Cognitive Career Theory

Social cognitive career theory (SCCT), developed by Lent et al. (1994), extends Bandura's (1986) general theory and contributes to the understanding of how people form interests, make choices, and accomplish academic and occupational success (Lent, Brown, & Hackett, 2000, p. 36). Social cognitive career theory focuses specifically on the cognitive-person

variables of a) self-efficacy, b) outcome expectations, and c) goal representations (Lent et al., 1994, p. 83) in combination with other person-specific aspects, including gender and ethnicity, and in combination with environmental or contextual barriers and supports, including those of a social, cultural, or economic nature (Lent et al., 2002, p. 36). While many previous career development researchers isolated person-specific factors of career development and behavior, often emphasizing a person's interest or measured skill set, social cognitive career theorists seek to understand how individual cognitive elements interact with context-sensitive barriers and supports in an effort to guide career and experiential/learning interventions (2002).

This social cognitive career theory framework has important implications for interdisciplinary research and collaboration in particular. It can also, in part, help explain when scholars who are knowledgeable and skilled in a respective discipline struggle unexpectedly with crossing disciplinary boundaries for which they may have a strong sense neither of self- and collective efficacy relative to the collaborative research process nor of outcome success. Research that provides empirical support to the SCCT is complementary, though often running on a parallel track, to the emerging research in team science and interdisciplinary collaboration. Even as early interdisciplinary efforts focused on the more easily identifiable organizational or contextual influences, early career theories also focused on more trait- or context-specific conditions for career development (Niles & Harris-Bowlsbey, 2005, p. 39). Although the different areas of study use different language for describing the complex interplay between person, team, and context, both social cognitive career theory and the foundational work on collaboration readiness offered by Stokols, Hall, et al. (2008) offer a view of the complex interplay of collaboration barriers, supports, and coping strategies.

As such, if self-efficacy and collective efficacy are both influenced by experiences and outcome expectations, and if competencies are indeed developmental and context-specific, then the question becomes: What experiences, activities, and interventions can academic leaders—those interested in facilitating interdisciplinary research collaboration—offer to emerging scholars so that they not only have the knowledge and skills they need but can also, as much as possible, develop a sense of efficacy when faced with IDRC's challenges?

Graduate Research Education and Training

Evidence that interdisciplinary and team collaborations are increasing across virtually all disciplines (Hicks & Katz, 1996; Wuchty et al., 2007) and the conceptualization of competence as *developmental, impermanent, and context-dependent* (Kaslow, 2004) have important implications for emerging scholar training and graduate education, especially in light of escalating scrutiny for higher education to be "more relevant" in preparing graduates for a variety of careers that address complex world challenges (Brennan, 2007). It is clear that while structural supports are necessary, alone they are insufficient for creating the context and conditions that enable effective interdisciplinary research collaboration. Interdisciplinary research teams very often fail or succeed based upon the complex interactions of many individual members, each of whom carries into the collaboration a unique set of experiences, skills, attitudes, and beliefs.

Emerging research provides evidence that specific individual-level competencies, i.e., *knowledge, skills, and attitudes*, needed for effective interdisciplinary research collaboration, once correctly identified, can be nurtured in order to improve IDRC competence (Gebbie et al., 2002; Larson et al., 2011; Larson & Begg, 2011). The presumption that graduate school training and education are critical places where specific interdisciplinary competencies and learning

opportunities should occur has been suggested in extensive documentation by groups including: The Brookings Institution; Council of Graduate Schools; Institute for the Advanced Study at Princeton; National Board on Graduate Education; Association of American Universities; National Science Foundation; House Committee on Science; Committee on Science, Engineering, and Public Policy of the National Academy of Sciences; and the Carnegie Foundation for the Advancement of Teaching (as cited by Nyquist et al., 1999, p. 26).

The call for graduate education improvement and for greater scrutiny regarding the relevance of graduate training to properly prepare students for a broad range of careers and for interdisciplinary competence is not new (Heiss, 1968; Lagemann, 2000; Lagemann & Shulmann, 1999; Brennan, 2007). Nonetheless, there is an escalating urgency to ensure the relevance of graduate education that will enable emerging scholars and scientists to actively participate in interdisciplinary research and endeavors that address the world's most critical challenges (Carnegie Foundation, 2003; National Academy of Sciences [NAS], 2004; Eisenhart & DeHann, 2005). Nonetheless, although much has been documented about structural and team supports for collaboration, much less is clearly understood about what learning experiences may facilitate *individual* competencies for effective interdisciplinary research collaboration.

Nyquist et al. (1999) asserts that in spite of a "sobering" number of reports that call for change in graduate education, there has been seemingly little effect, and the extensive calls for reform merely echo older ones that focus on precisely the same issues: "time-to-degree, preparation for teaching, the need to foster an understanding of faculty roles and the academy, effective mentoring, overproduction, narrowness of—or disconnected—specialization, and economic issues" (p. 26). Structural issues requiring attention and change seem to dominate most existing research on graduate reform (Bowen & Rudenstine, 1992; Seagram, Gould, &

Pyke, 1998). In spite of evidence of the need for deeper change, scholars note the difficulty of implementing it in the highly structured world of higher education and the difficulty of unpacking the complexities of doctoral education and moving our understanding of competencies to curriculum development (Caraccio, Wolfsthal, Englander, Ferentz, & Martin, 2002; Damrosch, 1995; Gardner, Hayes, & Neider, 2007; Siegfried, Getz, & Anderson, 1995).

Recent studies conducted to inform graduate training efforts relate interdisciplinary competence and development to more complex issues, including what beliefs and attitudes graduate students bring into and how they perceive the graduate school experience (Anderson & Swazey, 1998), socialization and the development of professional identity (Austin, 2002; Boden, Borrego, & Newswander, 2011), faculty assumptions regarding what students know when they enter graduate school in relation to student assumptions about faculty and other careers available post-graduation (Fischer & Zigmond, 1998; Golde & Dore, 2001), graduate students' cognitive schema, i.e., patterns and mental models (Bieber & Worley, 2006), neglected influences of trainees' attributes and attitudes during the graduate education process (Noe, 1986), and a broad range of career development issues, including those investigating meaning of work and work-life balance issues (Mason, Goulden, & Frasch, 2009).

Current Context for Doctoral Education With Consideration for IDRC

In practice, persistent challenges within the context of doctoral education present serious carry-forward problems for young scholars and scientists as they embark on a variety of careers within academia and across a broad range of professions. While most of these careers will require some form of interdisciplinary collaboration competence, students and even new PhD alumni report feeling inadequately prepared (Gaff, 2002). Numerous studies of graduate students and alumni suggest that preparation falls short in several ways that include: a lack of

systematic, comprehensive career education; little feedback and mentoring; scant information about various career options; and misunderstandings about the reality of academic professoriate job search and career issues (Golde & Dore, 2001; Lovitts, 2001; Nyquist et al., 1999). In a comprehensive review of the literature on graduate education, Gaff (2002) concludes:

> These studies point to a gap between the focus of doctoral programs and the work actually expected of those who hold the highest degrees. The evidence is beginning to accumulate that there is a mismatch between doctoral programs and the tasks that Ph.D. alumni do in their work, whether in the academy or in some other arena. (Gaff, 2002, p. 12)

Nerad and Cerney's (2000) survey of over 6,000 PhD alumni revealed that although workplace skills such as teamwork, collaboration, interdisciplinary work, and organizational and managerial skills are required in a variety of academic and non-academic positions, fewer than 20% of the survey respondents reported doctoral experiences that supported those skills. A decade later, there is undoubtedly more dialogue but still woefully inadequate systemic change (Hartesveldt & Giordan, 2008, p. 15, as cited by Mitchell & Weiler, 2011, p. 60). Larson, Cohen, et al. (2011) caution, "Although interdisciplinarity has become a favored model of scholarly inquiry, the assumption that interdisciplinary work is intuitive and can be performed without training is short-sighted" (p. 29).

There are many practical difficulties in developing comprehensive graduate training opportunities. Some of the difficulty may be in the creative tension between graduate student preparation efforts that focus on strengthening the "hard skills" and discipline-specific knowledge, as documented in the literature by Golde and Gallagher (1999), and those efforts to

develop "soft skills" that seem more elusive to define but may critically facilitate collaboration across disciplinary collaborations (Hartesveldt and Giordan, 2008, p.15). In looking specifically at developing the next generation of climate change scholars, Mitchell and Weiler (2011) conclude that although most graduate level programs provide PhDs with deep disciplinary knowledge and skills, they still do not do nearly as well at providing a meaningful foundation for interdisciplinary work (p.54).

Fiore and Bedwell (2011) recognize the fundamental importance of task-work competences but argue that team science and interdisciplinary competence require teamwork training, particularly in interpersonal communications and relationship-building skills. Earlier efforts by Metz (2001) to facilitate a doctoral seminar for students preparing for diverse research careers support Fiore's assertion that both types of skills are needed. Metz characterizes the inherent difficulty in helping doctoral students understand researchers from quite different disciplinary traditions of theory and method and enabling them to explain their own research to others as well. According to Metz:

> The border crossing and the examination of first premises in the seminar comes at a point in students' lives when they are forming incomplete, fragile understandings of research in their disciplines. Through their time in graduate school, they are becoming apprentices, then tentatively becoming practitioners of research. This course may seem to intrude on that process, as it throws assumptions into doubt, suggesting that there are alternative meta-theories, theories, methodologies, methods, and meaningful research questions. Strong and sensible people can feel threatened in that situation. Intellectual difficulty only compounds the threat. (p. 15)

Metz cautions that there is a difference between interdisciplinary *conversation* and interdisciplinary *research* and offers that she has "seen too much that exhibits a drop in quality rather than an increase in complex work" (2001, p. 17). That IDRC is both popular and important, she cautions, does not make it accessible.

Elements of Effective Graduate Education and Training

The current investigation defines competencies as *knowledge, skills, and attitudes* and adopts a consistent definition of training that is generally accepted and included in empirical studies across many disciplines. Campbell, Dunnette, Lawler, and Weick (1970) first defined training as planned learning experiences developed for the purpose of bringing about permanent changes in an individual's *knowledge, attitudes, or skills*. Kirkpatrick (1967) offered an early model of training outcomes that is still useful today and comprises four training outcomes: 1) trainee reaction to training content and process, 2) learning as measured change in knowledge or skills, 3) behavioral change, and 4) improvements in measurable individual or organizational outcomes. Noe (1986) extends Kirkpatrick's work by considering trainee attitudes, interests, values, and expectations and how these may enhance or hinder the effectiveness of training. (p. 737). Noe offers that personal efficacy expectations are important to consider in training, particularly as they may influence a trainee's responses to learning and change within the context offered (p. 741).

If individual self-efficacy and collective efficacy are both influenced by experiences and outcome expectations, and if competencies are indeed developmental and context-specific, then the question becomes: *What educational experiences, activities, and interventions can academic leaders offer to emerging scholars, in the interest of facilitating interdisciplinary research collaboration, so that they not only gain the knowledge and skills they need but also develop a*

sense of efficacy when faced with the challenges of interdisciplinary research collaboration? Currently there is a gap in empirical research that addresses these questions. This study was undertaken with the assumption that one of the best options for identifying the requisite competencies and training strategies may begin with leveraging the wisdom of scholars and scientists experienced in effective interdisciplinary research and graduate education.

Chapter 3: Methodology

Introduction

This study addressed gaps in the literature by identifying 1) core *individual* competencies needed for effective interdisciplinary research collaboration (IDRC) and 2) specific graduate-level learning activities that facilitate the development of those individual competencies. The results of this investigation are intended to provide new information and support for academic leaders who are interested in developing relevant training and career development opportunities for graduate students, across virtually all disciplines. This is especially important as emerging scholars and scientists will likely participate in interdisciplinary research collaboration in a variety of contexts upon completion of their studies. It is believed that the results will be applicable to future qualitative and quantitative research specifically focused on facilitating interdisciplinary collaboration readiness and development.

Research Questions

This investigation addressed the following two research questions:

1. What are the key individual *competencies* (knowledge, skills, and attitudes) needed for effective interdisciplinary research collaboration?
2. What specific *learning activities* will help graduate students develop the identified competencies needed to effectively engage in interdisciplinary research collaboration?

Methodology

This investigation employed the Delphi research technique to capture both qualitative and quantitative data collected from a group of experts recognized for their exemplary achievements

in IDRC. The Delphi research methodology was developed in the 1950s by Norman Dalkey of the RAND Corporation to gather expert judgment about military defense strategies (Dalkey & Helmer, 1963). It is now an accepted technique and has been employed in diverse studies spanning multiple disciplines (Skulmoski et al., 2007; Zami & Lee, 2009). The Delphi scientific methodology is designed for research of complex problems or issues requiring the input of many subject matter experts and is particularly well-suited when the experts are from diverse backgrounds, do not have a history of communication with each other, and are remotely located from each other (Adler & Ziglio, 1996; Linstone & Turoff, 1975).

Though the Delphi methodology originated as a traditional pen and paper survey technique, web-based Delphi methods similar to those employed in a study by Colton (2002) and as described by Hatcher and Colton (2007) have been developed and were used for the purpose of this investigation. These more recent efforts investigate methods of collaborative knowledge construction in highly structured virtual environments, often with diverse and geographically dispersed subject matter experts (Barbera, 2006; Hatcher & Colton, 2007). This study allowed for a group of experts in different time zones and countries to explore two specific research questions and to contribute their ideas to what others suggested in ways that might otherwise have been quite cumbersome.

The Delphi technique is based on the premise that *collective intelligence* of non-collocated experts offered anonymously enhances the understanding of emerging issues and questions for which there is not yet common understanding, extensive published information, standard practice, or empirical research (Whitehead, 2007). The Delphi method involves structuring the iterative group communication and problem solving process so that the experts bring a collective intelligence to bear on the research questions posed. In this case, the questions

were submitted to the group via electronic survey and focused on identifying and confirming *individual IDRC competencies and recommended graduate education activities for facilitating those competencies*. In response to pre-determined research question prompts (see Appendices E through G), experts contributed knowledge and information in the first round. After the responses were collected and reported back to the group, the experts again gave and received feedback about the collective responses in Round 2. This iterative process allowed for individual and group assessment of the emerging group view and adjustment of individual views and general group consensus relative to the question being studied (Linstone & Turoff, 1975).

Consistent with this study, Skulmoski et al. (2007) and Rowe and Wright (1999) identified four key characteristics of a classical Delphi study as the following:

1. Anonymity of experts to allow free exchange of ideas and ranking based on merit of contribution versus record, relative standing, or persuasive abilities of expert;
2. Iterative process to collect opinions and then provide feedback to experts who may then discuss, modify, and refine their individual opinions and group consensus;
3. Controlled feedback moderated by an objective researcher;
4. Statistical aggregation of expert opinions captured in both quantitative and qualitative analysis of data.

Special Validity Considerations of the Delphi Method

Conducting a Delphi study involves four specific steps: designing the questionnaire, selecting the participants, monitoring participation, and analyzing the responses (Olshfski & Joseph, 1991). As with any research methodology, there are considerations unique to the structure of the Delphi design that need special attention prior to the study. These considerations include: criteria for and selection of the expert panel, sample size, the development of the

questionnaire items, definition of consensus and how to interpret non-consensus, and data analysis and verification (de Villiers, de Villiers, & Kent, 2005).

Population: Selection and Definition of Exemplars

The Delphi technique is a methodology that relies on the "informed intuitive opinions of specialists" (Helmer, 1983, p. 134), and though the results are based on the subjective opinions of the experts, they are considered to be more reliable and more objective in addressing the research question than individual opinions (Zami & Lee, 2009). The Delphi method is intended to inspire true, albeit controlled, vigorous debate, independent of personalities (Gordon, 1994). The vigorous "debate" that Gordon (1994) refers to concerns the individual members' contributions to the specific, tightly structured questions and the opportunity to challenge, accept or comment on the opinions posed by others. As insights are offered anonymously and reflected back to the group by the objective researcher, they avoid being swept up in communication and even status issues that can potentially sidetrack the discovery process. "The value of the Delphi method rests with the ideas it generates, both those that evoke consensus and those that do not" (Gordon, 1994, p.4).

The success of any Delphi study depends upon the quality of the panelists selected and the level of their participation (Dalkey and Helmer, 1963). In general, experts must meet four specific criteria: knowledge and expertise with the issues being studied, capacity and willingness to participate, time to participate, and effective communication skills (Adler & Ziglio, 1996, Zami & Lee, 2009, p. 43). For a list of sources for the experts to be invited to participate in this study, see Appendix A. The generosity and willingness of the panelists to afford the time needed to complete this study were remarkable.

For the purposes of this study, experts met the following criteria:

1. Noted scholarship in area(s) of interdisciplinary research collaboration with record of achievement, as measured by publications, peer review, conference proceedings, and other activities, and as approved for participation by panel of advisors;
2. Distinguished record of scholarship (publications/awards) on interdisciplinary research;
3. Earned doctorate;
4. Past or present service in graduate advising/mentoring role;
5. Record of scholarship outside of core discipline.

Additional demographic information was collected on each expert and included gender, country of residence, discipline, and years of experience.

Sample Size

Linstone and Turoff (1975) suggest a panel size of anywhere from 10 to 50 for most Delphi investigations, smaller when the sample is homogeneous and larger when the sample is more heterogeneous. Additional scholars also recommend that the sample size not be less than 10 but suggest further that extending the sample beyond 30 experts would burden the data analysis process and not likely result in enhanced results (de Villiers et al., 2005) Although the common thread in this particular study was interdisciplinary expertise, the intent was to compose a panel of experts from diverse disciplines. Accordingly, the researcher met the goal to include 15 to 20 experts who have achieved distinction, as defined by professional standing and publications, as well as honors, awards, and peer review. See Appendix A for criteria and sources of panelists.

Selection and "Balancing"

Particularly relevant for a study involving interdisciplinary scholars, it was necessary to make sure that there was a broad range of disciplines represented on the expert panel. Representation was sought from fields including:

- Humanities: especially Philosophy;
- Social Sciences: Psychology, Economics, Anthropology;
- Natural Sciences: Space, Earth, Life, Chemistry, Physics;
- Formal Sciences: Mathematics, Computer Science;
- Applied Science and Engineering: Education, Environmental Science, Health.

An initial group of 30 prospective participants was identified by the researcher from a variety of sources (See Appendix A). Each was sent a personalized email invitation to participate (See Appendix B Example). Gordon (1994) proposes that in compiling the invitation list, an acceptance rate between 35% and 75% be anticipated (p. 7). Of the 30 scholars invited, 20 agreed to participate; however, one agreed after the deadline had passed and Round 2 had already been launched. Two prospective panelists declined the invitation due to other pending deadlines, and no answer was received from seven. A recommendation was offered for an additional panelist, and one invited scholar indicated he would not participate in the study but would be willing to schedule a discussion of the topics.

The 19 panelists who agreed to participate and the recommended panelist who was added after accepting an invitation all received a follow-up email with the Informed Consent Form and a reiteration of study intent, along with the access instructions for the Round 1 Survey (see Appendix C). An introductory message preceding the survey reiterated the focus of the investigation and the panel's objectives and indicated the expected sequence of rounds and

timeline. Participants were assured anonymity and asked to confirm their willingness to participate by submitting the electronic Informed Consent Form in order to proceed to the survey (Appendix D).

Questionnaire: Research Questions Posed in Four Iterative Rounds

Two distinct research questions were posed to the group in successive rounds. The panel reviewed an initial list of competencies and offered three additions in Round 1. In Round 2, the panel reviewed the aggregated results of Round 1 and indicated whether they agreed with, disagreed with, or were neutral to the new competencies offered. In Round 3, the panel identified learning activities for each of the competency statements achieving consensus (24). Finally, in Round 4, the panel was able to review examples of the activities and the clusters identified for the activities by competency.

For details, see Appendix E and Appendix F. A comprehensive review of the existing and emerging literature informed the formulation of the research questions as posed. Gebbie et al. (2008) offered a preliminary list of interdisciplinary research competencies that were used with permission as a starting point for the Round 1 discussion. A small team of expert advisors, not part of the Delphi panel but including Dr. Kristine Gebbie, reviewed the wording, and the Delphi questionnaire was pilot-tested prior to distribution.

Appendix D shows the electronic Round 1 survey distributed to the 20 participants to confirm and identify interdisciplinary research collaboration competencies. Respondents were asked to indicate their agreement with the original list of 17 competencies offered and could also add three additional competencies to the list. The results of Round 1 were collected, synthesized, and reported back to the group during Round 2 for additional feedback and consideration (Appendix E). An established threshold for consensus was set at 75% agreement, meaning that

only those original items that 75% or more of the participants agreed were important for effective interdisciplinary research collaboration were included in the final list.

The results of Rounds 1 and 2 served as the basis for Round 3, corresponding to Research Question Two to determine learning activities that facilitate the agreed-upon essential competencies (see Appendix F). Specifically, in Round 3, experts were provided with the complete list of competencies identified at the end of Round 2 and that received agreement. For each competency, experts were asked to identify learning activities for graduate students that facilitate the development of that competency. The iterative process continued in that the data were collected, coded, synthesized, and reported back to the group for a final review in Round 4.

Role of the Researcher

In a Delphi study, the role of the investigator is strictly objective, and as Crisp, Pelletier, Duffield, Adams, and Nagy (1997) offer, this is methodologically, pragmatically, and ethically necessary a) to prevent feedback manipulation, b) to ensure that a comprehensive view of the data is taken, and c) to avoid influence in the actual decision-making process.

This investigation employed the data gathering and analysis process outlined below.

The Delphi Process:

1. A review of the literature informed the creation of the initial structured question to be posed to the panel of experts in Round 1.
2. Identification and invitation/selection of expert panel based on criteria for excellence in IDRC, as informed by literature review and advisory panel. Criteria included: expert experience, publications, awards, presentations, and formal roles (including committee and professional societies) relevant to interdisciplinary research.
3. Round 1 of the Delphi: *Identifying Competencies for IDRC.*

4. Round 2: Feedback and assessment of responses received from Round 1.
5. Round 3: Identifying Specific Graduate Education Activities that Facilitate IDRC Competencies.
6. Round 4: Review of learning activities and clusters identified in Round 3.
7. Data Analysis and inclusion of individual qualitative statements.
8. Documentation of research results with academic validation, situating the findings in the theoretical context of Social Cognitive Theory and Social Cognitive Career Development Theory, with particular attention to Graduate Education and Career Development Issues.

Generalizability

As Gordon (1994) notes:

> Delphis do not (and are not intended to) produce statistically significant results; in other words, the results provided by any panel do not predict the response of a larger population or even a different Delphi panel. They represent the synthesis of opinion of the particular group. (p. 4)

That said, based on expert opinions, the results of this study are intended to be useful to a broader group of higher education professionals and academic leaders interested in understanding, first, the most critical competencies emerging scholars will need to have to effectively participate in IDRC and, second, recommended graduate level learning activities that facilitate the development of those competencies. Although contextual variations will affect specific translatability of the findings, generalizability of the findings to a broad range of academic leaders is anticipated.

Data Analysis

The data collected in this study were analyzed using both quantitative and qualitative methods. In order to address the first research question concerning competencies, consensus measures were captured for the data collected in Rounds 1 and 2, using simple descriptive statistics. The total percentages of participants who agreed with, disagreed with, or were neutral to each competency statement were calculated. Consensus for items to be included on the final list was considered reached when 75% of the respondents agreed an item was important. Consistent with Delphi methodology, the iterative review rounds allowed participants a chance to review the aggregated consensus ratings, to reflect on their own initial responses, and to modify them if desired (Adler & Ziglio, 1996; Delbecq et al., 1975; Linstone & Turoff, 1975).

Quantitative analysis indicated which competency statements achieved group consensus after Round 2. At that point, qualitative content analysis (Leedy & Ormrod, 2010) was conducted to provide a detailed, systematic examination of the content of the input in order to illuminate specific patterns and themes of the added competencies and subsequent learning activities. In addition, a constant comparative method (Glaser & Holton, 2004) was employed for open coding and to create the activity clusters that emerged as associated with the learning activities. Simple descriptive statistics, specifically frequency counts, were compiled after Round 3 to depict the coded data.

Coding

As stated by Glaser and Holton (2004):

> In the case of qualitative data, the explicit goal is description. The clear issue articulated in much of the literature regarding qualitative data analysis (QDA) methodology is the accuracy, truth, trustworthiness or objectivity of the data. This worrisome accuracy of

> the data focuses on its subjectivity, its interpretative nature, its plausibility, the data voice and its constructivism. Achieving accuracy is always worrisome with a QDA methodology. (para. 2)

The methodology for treating qualitative data is frequently the focus of discussion and even debate (Walker & Myrick, 2006) among scholars, and at particular critical points in the analysis of this data, the researcher was required to make sure the themes and patterns identified were emerging from the data and reflected the voices of the expert panelists, rather than the researcher's own interpretation. More detailed description will be provided in the following results section, but for the purpose of clarity about methodology, it is important to note two of those critical times.

First, in Round 1, when 45 additional competencies were suggested, the list became lengthy and there was a concern that the number of items about which they were expected to voice agreement, disagreement, or neutrality would overwhelm the panelists. Nevertheless, consistent with the Delphi methodology, it was critical that the competency statements reflected the voice of the experts; for this reason, the statements were shared back in original form. Additionally, any edits suggested for any of the original competency statements in Round 1 were also shared back to the group verbatim in Round 2.

Secondly, when the learning activities data were collected, the data were reviewed for open coding twice. The data were then separately reviewed using a selective coding methodology that sought to code the data according to an existing categorization or framework of learning activities. It was at that point decided to adopt the open coding methodology, as it appeared that forcing the data into an existing categorization versus letting the clusters emerge was in fact manipulation of the data and could possibly compromise the voice of the experts.

Frequency Counts

Comments shared by panelists reflected frustration with having to consider learning activities for each individual competency statement rather than write an open-ended response. As described in greater detail in Chapter Four, this was an intentional design of the survey's structure so that more difficult-to-address competencies would not be lost or glossed over if more general responses were allowed. This structure forced panelists to consider each competency in a very focused manner. Nonetheless, as some panelists noted, some suggestions addressed multiple competencies, e.g., "graduate seminar," and appeared multiple times across the competency statements.

Additionally, although most of the suggested activities fit neatly into the cluster categories that emerged from the data, it was evident that some of the suggested learning activities could be considered appropriate for more than one of the emergent clusters. For example, "journal club/case study" was tagged in both the journal club and case study clusters. In those cases, where the learning activity suggested actually involved more than one learning activity cluster, it was tagged and coded for each category.

Summary

In response to calls for graduate education that will prepare students to help address the world's most challenging problems, and with the support of funding agents and the enthusiasm of emerging scholars and scientists, many academic leaders have established goals to develop effective graduate education opportunities to promote interdisciplinary research collaboration competence. In order to be effective in those training efforts, research needs to address gaps in the understanding of what specific individual competencies are most critical and what graduate education activities are most useful for facilitating those competencies.

The methodology adopted in this research captured the insights and practical guidance of exemplary scholars known for their leadership and competence in interdisciplinary research and education. It is hoped that this work will contribute to efforts to properly prepare graduate students to effectively participate in interdisciplinary collaborations in a variety of work environments upon graduation. The findings of this study will be situated in the context of Social Cognitive Career Theory and are intended to have specific implications for graduate education programs and curriculum development.

Chapter 4: Results

Introduction: Participants

The success of a Delphi study rests in large measure upon the quality of the experts who participate on the panel, and there is always concern that the time and commitment that the extended rounds requires will result in disruptive attrition. It is frequently cited in the literature to anticipate participant response rates between 40 and 75 percent (Gordon, 1994, p. 7). In this study, a strong response rate was achieved. Twenty scholars initially agreed to participate in the study, though one withdrew prior to commencement. The 19 remaining scholars completed the Round 1 survey sent to them electronically (SurveyMonkey LLC, Portland, OR). These 19 experts account for the baseline from which subsequent completion rates were calculated.

Nineteen experts completed Round 1 (100%), 15 completed Round 2 (78.94%), 16 completed Round 3 (84.2%), and 16 completed Round 4 (84.2%). Explanations for changes in participation after Round 1 were offered by three of the panelists and included: illness of family member, international relocation, and deadlines for completion that conflicted with seasonal holidays and university breaks occurring in both November and December. In Round 2, a technical issue prevented the completion of a survey by the deadline requested.

It is important to note that for this study, participants were given two weeks to submit their responses after receiving the survey for Rounds 1, 2, and 3 and one week for Round 4. A reminder was sent two days prior to the deadline for those who had not yet completed the survey, and a second reminder was sent the day of the deadline. Because each successive round relied on aggregating and analyzing the responses from the previous round, the entire timeline was tightly constructed and did not allow late entries to be added back. In one situation, a participant

contacted the researcher and indicated she had received the third survey and realized that she had missed the second survey. She asked which survey to complete and was instructed to continue on with Round 3.

Eleven males and eight females participated from four different countries: Australia (1), Canada (2), New Zealand (1), and the United States (15).

Diversity of academic and disciplinary backgrounds and diversity of subsequent professional/departmental affiliation was achieved and is highlighted below with frequency counts noted in parenthesis:

Undergraduate/Master's

Applied Mathematics
Applied Psychology
Biochemistry (2)
Biology (4)
Chemistry
Counseling and Guidance
Economics (2)
Education
English (2)
French
Geography
Geology (2)
Humanities-History
Interdisciplinary Forensic Psychiatry
Latin
Mathematics
Philosophy (4)
Physics
Psychology
Statistics

Doctoral Degrees:

Behavioral Pharmacology
Biochemistry
Economics
Education
Education, Human Development, and Psychology
English
Geography

Human and Organization Development (Group/Team Behavior)

Immunology

Industrial/Organizational Psychology

Interdisciplinary Philosophy of Science

Law

Microbiology and Immunology

Nutritional Sciences

Oncology

Philosophy

Statistics

Systems Engineering and Operations Research

Zoology

Additional Degrees/Certifications:

Law

Leadership, Collaboration, Creativity, Innovation

Postdoctoral: Neuroscience

Career Guidance, Education

Informatics, Cardiology, Neonatology, Translational Science

Molecular/Chemical Ecology, Entomology

Non-Profit Management

Organizational Learning

Of the 19 participants, 15 were affiliated with research universities, one was affiliated with an International Policy Centre, one was affiliated with a National Health Institute, one was an independent education and research consultant, and a final panelist transitioned during the study from an academic-university affiliation to a major research publishing institution. The panelists were heavily concentrated in research/university institutions, consistent with the intent of the study to identify learning activities within the context of graduate education. Position titles of the participants included:

Assistant Professor

Principal Investigator

Professor

Professor of Humanities, English, and Faculty Fellow for Interdisciplinary Development in Division of Research

Associate Vice Provost for Professional Development

Associate Vice President for Research

Director

Chief Operating Officer

Associate Dean, Professor

Assistant Center Director

Director and Professor

Professor

Dean of Engineering

Vice President

Associate Professor

Deputy Scientific Director

Director and Professor

Associate Director

Two critical areas of panelist expertise had been identified as part of the selection criteria: interdisciplinary research collaboration experience and graduate education and training experience. Panelists reported interdisciplinary research experience between 3 and 37 years, with 13 out of 16 panelists having achieved more than 12 years of experience and 10 out of 16 having achieved more than 15 years of experience in IDRC. The mean number of years of interdisciplinary research experience was calculated to be 18, with a median of 16. Secondly, the panelists reported between 3 and 40 years of graduate education and training experience, with a mean of 20.1 and a median of 21. Fourteen out of 16 panelists had more than 10 years of experience, and 10 out of 16 panelists had more than 15 years of experience in graduate education.

Instrumentation and Informed Consent

The was an entirely virtual study. Prospective panelists were invited to participate in the study via email and were asked to indicate their intention to participate by sending a confirmation reply email by the deadline provided. When the deadline arrived, all invitees (20) who initially accepted the invitation were sent a second email with instructions to access the survey; on the same day, however, one invitee withdrew, leaving 19 panelists remaining. All data were collected via electronic survey rounds (SurveyMonkey LLC, Portland, OR). The communication for Round 1 included the electronic consent form required to proceed to the survey and a letter of introduction that reiterated the purposes of the study and provided a definition of competency according to Parry (1996). Also itemized with proper citation was a list of the 17 competency statements identified by Gebbie et al. (2008) as necessary for interdisciplinary health research. This list of 17 competencies served as the initial framework for discussion and was important in modeling the language of competency statements and providing general guidance at the start (see Appendix F).

Round 1 – Research Question 1

What individual competencies (knowledge, skills, attitudes) are needed for effective interdisciplinary research collaboration?

Part I. Participants were informed that the initial list of competencies was not intended to be restrictive and that they would be provided an opportunity to add competencies they believed were important yet missing from the original list. For each of the 17 items, they were asked to indicate whether they agreed, disagreed, or were neutral that the identified competency is necessary for effective interdisciplinary research collaboration. In the instructions, a key

distinction was made between the previous research team's goal to look at competencies required for interdisciplinary health research and the current study intended to look at IDRC in a broad range of settings. In addition to rating agreement with each competency, panelists were provided a space, if they desired, to suggest modifications to the original wording and/or to provide a brief comment for each competency.

The 17 competencies originally identified by Gebbie et al. (2008) for interdisciplinary health research were reviewed by the group for validation. Consensus was established at the 75% rate of agreement, meaning that 75% or more of the panelists had to indicate they agreed that the item was important for effective interdisciplinary research collaboration more broadly applied. Two of the 17 competencies achieved consensus and were included on the next round list. Edits were suggested for nine of the competencies. (These edits were later reviewed/accepted in Round 2, meeting the 75% agreement rule as well.) The six remaining original competencies did not achieve consensus, though some of these were edited and appeared in revised form on some of the panelists' lists of suggested additions.

Table 1: Competencies With Revisions

1. Use theories and methods of multiple disciplines in developing integrated theoretical and methodological frameworks.
   Agreed 71.4% Neutral 9.5% Disagreed 19.0%
   Recommended Revision:
   Work with others to use theories and methods of multiple disciplines to improve understanding of an agreed upon problem or issue.

2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary research protocols.
   Agreed 81.0% Neutral 0.0% Disagreed 19.0%
   Recommended revision: Integrate concepts and methods from other disciplines in designing research protocols.

3. Investigate hypotheses through interdisciplinary research.
   Agreed 57.1% Neutral 26.6% Disagreed 14.3%
   Consensus Not Achieved. Recommend deletion.

4. Draft funding proposals for interdisciplinary research programs in partnership with scholars from other disciplines.
   Agreed 85.7% Neutral 9.5% Disagreed 4.8%
   Recommended Revision: Draft research proposals in partnership with scholars from other disciplines.

5. Disseminate interdisciplinary research results both within and outside his or her discipline.
   Agreed 90.0% Neutral 0.0% Disagreed 10.0%
   Recommended Revision: Disseminate interdisciplinary research results to various audiences in multiple disciplines.

6. Advocate interdisciplinary research in developing initiatives within a substantive area of study.
   Agreed 61.9% Neutral 28.6% Disagreed 9.5%
   Consensus not achieved, recommend deletion from list.

7. Express respect for the perspectives of other disciplines. (Redundancy noted. Edits recommended, some within added competencies list.)
   Agree 90.5% Neutral 4.8% Disagree 4.8%
   Recommended Revision: Appreciate and draw value from the perspectives of other disciplines.

8. Read journals outside his or her discipline.
   Agreed 66.7% Neutral 14.3% Disagreed 19.0%
   Consensus not achieved. Additional competencies list addresses concerns expressed. Suggest deletion as stated.

9. Communicate regularly with scholars from multiple disciplines. (Consensus achieved, redundancy noted.)
   Agreed 100.0% Neutral 0.0% Disagreed 0.0%
   Recommended Revision: Communicate regularly with scholars from other disciplines.

10. Share research from his or her discipline in language meaningful to an interdisciplinary team.
    Agreed 100.0% Neutral 0.0% Disagreed 0.0%
    Recommend to accept as stated.

11. Modify his or her own work or research agenda as a result of interactions with colleagues from fields other than his or her own.
    Agreed 81.0% Neutral 14.3% Disagreed 4.8%
    Consensus achieved. No edits suggested. Recommend accept as stated.

12. Present interdisciplinary research at venues representing more than one discipline.
    Agreed 81.0% Neutral 14.3% Disagreed 4.8%
    Recommended revision: Present interdisciplinary research at venues outside of one's discipline and at venues representing more than one discipline.

13. Engage colleagues from other disciplines to gain their perspectives on research problems. (Consensus, but redundancy especially with Item 9 cited by several. Recommended edits and consolidation for final list.)
    Agreed 90.5% Neutral 4.8% Disagreed 4.8%
    Recommended revision: Engage colleagues from other disciplines to gain their perspectives on research problems, themes, or topics.

14. Interact in training exercises with scholars from other disciplines.
    Agreed 57.1% Neutral 33.3% Disagreed 9.5%
    Consensus not achieved. Recommend deletion from list as stated.

15. Attend scholarly presentations by members of other disciplines.
Agreed 80.0% Neutral 10.0% Disagreed 10.0%
Consensus Achieved. Recommend deletion due to redundancy especially with additional competencies list. (Item cited as outcome/activity versus competency.)

16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks.
Agreed 89.5% Neutral 5.3% Disagreed 5.8%
Suggested Edits:
A. Collaborate respectfully with scholars from other disciplines to develop interdisciplinary research frameworks.
B. Develop interdisciplinary research framework(s) in collaboration with scholars from other disciplines.

17. Author publications with scholars from other disciplines.
Agreed 81.0% Neutral 9.5% Disagreed 9.5%
Consensus but with qualified comments noting redundancy with Item 5. Recommend deletion due to redundancy and revision of Item 5 wording to include dissemination of research a) presentation and b) publication

Round 1 - Part II. Participants were asked to provide up to three additional competencies that they considered important but missing from the initial list. Forty-five (45) additional competencies were submitted by participants. Each of these competency statements would be reviewed for consensus in Round 2 and appear as presented in Table 2. Note: as distinguished from the 2008 study goal to establish interdisciplinary health research competencies, the panelists in this study were asked to identify competencies for interdisciplinary research *collaboration*. As will be discussed in Chapter 5, this word choice may have been one factor, among others, for the recurring emphasis on communications and team skills throughout this study.

Some of the 45 added items were redundant. At times, different panelists were suggesting basically the same additional competency yet choosing slightly different ways of expressing it. There was a concern that asking the panelists to review the entire number of additional competency statements (45) along with asking them to review again the results of the aggregated responses for the original competencies (17) would present a burden to the panelists in Round 2. However, consistent with Delphi methodology, it was critical that the participants

review the original competency agreement/disagreement results as well as the suggested additional competencies in the language provided by the experts without researcher interpretation or rewording. As Zami and Lee (2009) note, "Continuous verification throughout the Delphi process is critical to improve the reliability of the results" (p. 48). The nuances associated with the language of competencies carry disciplinary influences, and it was clear that in order to protect the integrity of the study, the wording for the added competencies in Round 2 had to be provided by the experts, not imposed by the researcher. It was explained in the instructions that Round 2 that any final redundancies would be sorted once agreement was established.

Table 2: Additional Competencies Recommended

1. Know individual personal strengths and weaknesses as related to interdisciplinary research.
2. Be assertive as a learner; asserts one's expertise sparingly.
3. Demonstrate broad intellectual curiosity to ask questions outside own discipline.
4. Subject his or her disciplinary discovery to interdisciplinary interpretation and scrutiny.
5. Know strengths and weaknesses of research approaches of other disciplines.
6. Teach and learn from collaborators, in self- or group-directed ways. (Includes learning from material artifacts produced by other disciplines and informal—non-classroom—styles of learning, which requires learning on-the-fly as needed rather than a structured acquisition of basic to more complex concepts.)
7. Willingness to engage with others to continually clarify language and the concepts that lie behind language, in constructive dialogue that enhances mutual learning and the construction of shared (or mutually understood) terminology and concepts.
8. Speak from one's own disciplinary perspective so that others hear "where you are coming from" in the ways in which your discipline identifies, thematizes, and explores its objects.
9. Take a meta-disciplinary stance to examine the perspectives of relevant disciplines including his or her own.
10. Engage in questioning the basic assumptions of all disciplines, including one's own.
11. Engage in self-critique recognizing the limitations of the interdisciplinary research process and outcomes and envisioning next research steps.
12. Understand what his/her own discipline can contribute to addressing a problem and how that differs from the contributions of other disciplines.
13. Maintain an open mind and suspend assumptions of one's own discipline so others can be heard.
14. Demonstrate critical awareness of the underlying assumptions of own discipline, its scope and contribution and limitations in addressing a given research question.
15. Learn the languages others use in their work.
16. Understand how to effectively manage conflict, feedback, and credit relative to interdisciplinary team research.
17. Know how to manage personal conflict while promoting substantive disagreement.
18. Know how to build trust among collaborators in an interdisciplinary team.
19. Engage in self-critique and in ongoing iterative review of stages of the research process and products that are generated, being open to revisions as needed.
20. Frame research questions or problems that are multi-dimensional, relevant, and viable and demand an interdisciplinary approach.
21. Understand key concepts and principles from participating disciplines of an interdisciplinary team needed to effectively communicate, interact and/or develop protocols and conduct research.
22. Recognize that other disciplines don't simply bring different perspectives on the research object, but literally bring their own objects to the project, and be able to operate from this understanding of what is going on in the collaboration.
23. Understand and respect different norms and expectations for responsible conduct of research within different disciplines,

including authorship and protection of human subjects.

24. Work collaboratively with equal power sharing and mutual learning of others' languages, modes of working, and epistemic worldviews.

25. Able to hear "where they are coming from" in the things one's collaborators say in terms of how their discipline identifies, thematizes, and explores its objects.

26. Contribute to the creation of collective intelligence that includes: thinking with team, adapting individual contributions, trusting value of other contributors, and negotiating differences.

27. Demonstrate familiarity with (the literature of) pertinent interdisciplinary fields and approaches.

28. Have knowledge of the strengths and weaknesses of the experimental approaches of other disciplines.

29. Develop team skills in order to strengthen team structure and dynamics.

30. Contribute effectively to the work of the team, e.g., being a team player, recognizing where one's work fits, having expertise to draw on most relevant aspects of own discipline for the problem at hand.

31. Know how to develop a shared interdisciplinary vision with collaborators, communicate it effectively, and revisit it at regular intervals to determine if changes are required.

32. Understand how to effectively deal with conflict and credit when working in interdisciplinary team.

33. Use group methods of brainstorming that get people out of their disciplinary boxes.

34. Build skills for team facilitation and leadership.

35. Reflect as a group on collaborative interactions and outcomes.

36. Engage in dialogue, negotiation, and iterative learning processes to craft common ground and leverage synergies across disciplines/perspectives.

37. Demonstrate familiarity with research products and key literature (e.g., journal articles, blog posts, data sets) of pertinent interdisciplinary fields and approaches.

38. Effectively interact with and contribute to varied educational opportunities with scholars from other disciplines, e.g., seminars, conferences, scholarly presentations, and research symposia.

39. Define experimental questions or identify problems that cannot be solved through a single disciplinary approach.

40. Integrate *insights* from multiple disciplines.

41. Develop feasible approaches to addressing the research hypothesis and conversely to abandon approaches that are not feasible. (A feasible approach is one in which time, talent, and funding all appear sufficient to make a contribution to the creation of knowledge.)

42. Engage in ongoing iterative review of stages of the research process and products that are generated, being open to revision as needed.

43. Question the very idea of "integration" as necessary for interdisciplinary communication and collaboration: What is integration and will it help achieve research goals?

44. Understand strategies for interdisciplinary team communication, including clarifying the meanings of key concepts and appreciating the perspectives of other disciplines.

45. Understand strategies for performing interdisciplinary research.

Round 1, Part III: Categories of Competencies. In Part 3, participants were asked to indicate whether or not they agreed with, disagreed with, or were neutral to the three broad categories that

Gebbie et al. (2008) identified to group the 17 competencies. Seven of the panelists indicated agreement that the three distinct categories of competencies identified by Gebbie's team—Research, Communicate, and Interact with Others—captured the main competency categories. More than half of the respondents, however, indicated they were neutral to (6) or disagreed with (6) the categories. Panelists suggested the categories overlapped and thus resulted in competency redundancies; they were therefore not necessarily useful to distinguish.

Round 2

This study employed the iterative review process, consistent with the Delphi methodology, that allows each participant to reflect on his or her own initial responses, as well as to view the responses offered by the other study participants in each successive round. Round 2 thus presented the results of Round 1, along with the list of additional competencies suggested by panelists. Revisions of the original competencies reflected the exact wording suggested by participant(s) but in limited instances reflected frequent suggestions to modify the original competency. For example, several participants indicated the wording "draft funding proposals" was too specific and recommended saying simply "draft proposals" though others just stated "drop funding" This recommendation was then put forward for the entire group to review.

Participants were informed that a final consolidated list of competencies that had achieved consensus would be used to identify learning activities in Round 3. This list would include competencies both from the original list and from among those additional competencies suggested by the panelists. The redundant competencies would be coded and combined prior to being listed. However, for the purpose of Round 2, panelists were informed that the wording used reflected that of the panelists and that they were simply to rate their own level of agreement with the item. They were informed that they were not expected to wordsmith each new

competency statement. This was important for minimizing participant fatigue and the possibility of losing panelists to a laborious process. As in the first round, panelists were afforded an opportunity to comment on each new competency, and some chose this space to reword the competencies in a way more meaningful to them.

Forty-five additional competencies were submitted by participants in Round 1 and were reviewed for consensus in Round 2. Of the original 19 participants who completed Round 1, 15 completed the entire Round 2 survey, one participant did not receive the link due to a technological issue that prevented data entry by the deadline, one participant sent a message of apology, and two did not complete without explanation. This is consistent with typical response patterns associated with Delphi studies and was actually stronger than anticipated given the length of the Round 2 survey (which included a review of the 17 original competencies, plus the 45 new items).

Of the additional 45 competencies, 20 did not achieve consensus (they received less than 75% agreement). The other 25 additional competencies did achieve consensus (they received 75% or greater agreement). The 25 additional competencies receiving consensus were sorted and coded, and redundancies between the competencies were noted. Coding was used to cluster the competencies to create the final list of 24 competencies that would be used in Round 3 to identify specific learning activities that might facilitate those agreed-upon important competencies. An independent researcher who was not participating in the study but who had expertise in competency research reviewed the final list.

Sorting the aggregated recommendations from Rounds 1 and 2 to an abbreviated list was an important challenge, given the nuance of wording and the level of agreement that some of the items had achieved. Three items were carried over from the original list that had to do with

presenting and disseminating research and drafting proposals. These received consensus but were criticized for being Learning Outcomes versus Individual Competencies. Nonetheless, each of these items achieved strong consensus, so the statements were included in Round 3 for identifying learning activities and then for careful review in the final data analysis (see Discussion).

Table 3: Aggregated List of Competencies Adopted for Round 3

Key competencies identified by the group as being important for effective interdisciplinary research collaboration. (Consensus achieved at 75% threshold.)

1. Demonstrate broad intellectual curiosity to ask questions across disciplines.
2. Recognize personal strengths and weaknesses as related to interdisciplinary research collaboration.
3. Demonstrate critical awareness of the underlying assumptions of own discipline and its scope, contribution, and limitations in addressing a given research question.
4. Engage colleagues from other disciplines to gain their perspectives on research problems, themes, or topics.
5. Share research from own area of expertise in language meaningful to an interdisciplinary team.
6. Collaborate with others to integrate theories, methods, and insights of multiple disciplines to improve understanding of problem or issue.
7. Subject own disciplinary discovery to interpretation and scrutiny by researchers from other disciplines.
8. Evaluate the assumptions and limitations of all disciplines in interdisciplinary collaborative initiatives.
9. Maintain an open mind in order to clearly hear perspectives of others during explorative interdisciplinary dialogues.
10. Understand how own expertise can contribute to addressing a problem and how that differs from the contributions of others in interdisciplinary collaborations.
11. Modify own work or research agenda as a result of interactions with colleagues from fields other than own.
12. Integrate concepts and methods from multiple disciplines in designing research protocols.
13. Develop interdisciplinary research framework(s) in collaboration with scholars from other disciplines.
14. Build trust among collaborators in an interdisciplinary team.
15. Understand strategies for interdisciplinary teamwork and communication, including clarifying the meanings of key concepts and appreciating the perspectives of other disciplines.
16. Develop team skills in order to strengthen team structure and dynamics.
17. Build skills for team facilitation and leadership.
18. Understand and effectively manage conflict, feedback, and credit relative to interdisciplinary team research.
19. Develop a shared interdisciplinary vision with collaborators, communicate it effectively, and revisit it at regular intervals to determine if changes are required.
20. Contribute to the creation of collective interdisciplinary knowledge that includes: thinking with team, adapting individual contributions, trusting value of other contributors, and negotiating differences.
21. Contribute to a variety of educational initiatives with scholars from other disciplines, such as seminars, conferences, scholarly presentations, and research symposia.
22. Present interdisciplinary research at venues representing more than one discipline.
23. Disseminate interdisciplinary research results to various audiences in multiple disciplines.
24. Draft research proposals and author publications in partnership with scholars from other disciplines.

Round 3 – Research Question 2

What specific graduate level learning activities facilitate the development of the individual competencies needed for effective interdisciplinary research collaboration?

Sixteen participants completed the third and most arduous round of the study. Participants were first asked to validate the aggregated list of 24 competency statements by answering the following question: *Do you consider the aggregated list of competencies, agreed by at least 75% of the participants in this study to be important for effective interdisciplinary research collaboration, acceptable for the purposes of further identifying learning activities that facilitate the development of those competencies?* All 16 validated the final list by indicating they considered it agreeable for the next task of identifying learning activities.

Next, for each of the 24 competency statements, panelists were asked to identify up to three specific graduate level learning activities that they believed would facilitate the development of those competencies. Panelists were instructed that they could list any type of graduate level learning activity that they considered helpful in facilitating the competency and that their suggestions could span the spectrum of highly structured and formal activities to less structured and even informal activities. Of the 16 panelists, 12 completed the entire survey by the two-week deadline. It was discovered within the first week, however, that respondent input was lost if the panelist did not progress through the entire survey and click "Submit" at the end. It is believed that this survey construction issue may have resulted in loss of some data for four of the respondents, and the survey was modified midway to accommodate the need to capture data as it was entered, to allow panelists to save and return to work in progress, and to allow panelists to skip an item if so desired.

Learning activities were identified for all of the competencies and there was a frequency range of suggestions from 9 to 34 per competency statement. Emergent versus selective constant comparison coding was employed to identify common clusters of learning activities in order to

articulate patterns and themes. These emergent patterns will be discussed in more detail in the next chapter. However, the results of learning activities by cluster and as associated with each competency statement can be seen in the grid below. Coding of the clusters and frequency counts were done without attribution to any of the panelists in order to minimize any researcher interpreter bias. Eighteen distinct clusters of learning activities were identified and include the following with the number of associated items included in parenthesis: coursework (66) with subcategory graduate seminar (23 of the 66), writing (49), group research (46), presentations and student teaching (42), team building and communications (40), team projects (38), reading (36), mentoring and consulting (29), self-assessment and reflection (26), case studies (24), peer advisory (23), formal meetings (21), independent research (21), special events (17), workshops (11), self-study (7), and informal meetings (4).

LEARNING ACTIVITIES BY CLUSTER (in order of frequency):

Coursework	66
Unspecified class with exercises	13
Courses—outside discipline	5
Courses—interdisciplinary	11
Special topics	14
Graduate seminars	23
Writing	49
Exercises	12
Diary/journal	2
Academic	22
Collaborative	10
Grant/proposal	3
Group Research	46
Presentations	42
General	23
Student teaching	12
Collaborative	7
Teamwork (communications focused)	40
Team Projects Within Class	38
Reading	36
Mentoring and Consulting	29
Self-Assessment/Reflection	26
Case Studies	24
Peer Assessment/Advisory	23
Formal Meetings	21
Journal clubs	8
Conferences	11
Graduate Student Council	2
Independent Research	21
Special Events	17

Brown bag lunches	7
Panels	3
Lectures	1
Research sessions/festivals	5
Retreats	1

Workshops 11

Self-Study 7

Informal Conversations.....4

Learning Activities Clusters with Examples (in alphabetical order by cluster):

The learning activity categories emerged from coding and are exemplified in the sample participant comments below.

Case Studies 24

- *Read case studies and histories of projects involving members of own discipline on IDR teams.*
- *Provide a short but complex case scenario, ask a small (perhaps interdisciplinary) group to look at it from multiple disciplinary angles and perhaps come up with the combined solution. Maybe even provide a framework to scaffold their discovery of multiple differing perspectives, their utility, and possible complementarity.*
- *Read case studies about effective interdisciplinary teams.*
- *Group analysis of case studies.*
- *Review case studies of successful and unsuccessful teams. Why do some succeed, others fail?*

Coursework 66

Unspecified class with exercises	13
Courses—outside discipline	5
Courses—interdisciplinary	11
Special topics	14
Graduate seminars	23

- *Coursework with associated projects to practice.*
- *Analyze multidisciplinary research papers, laying out the various contributions and definitions that had to be developed for success.*
- *Google for alternate platforms for sharing your work—make a list of possibilities, rate the possibilities on a scale of 1 to 5 in terms of how much interdisciplinary potential seems to exist, then choose and submit.*
- *Write out own research agenda in first column of a two-column page. In second column write about the same projects with the assumption that two other disciplines (of your choice) will*

be involved. Extra credit for more remote disciplines (e.g., two social sciences versus one social science and one physical science).

- *Take courses outside of primary discipline.*
- *Graduate course—project component for people to work together to actually practice this.*
- *It is possible to teach a course on the interdisciplinary research process.*
- *Take classes in scientific communication.*
- *A graduate seminar where students talk about their research.*

Formal Meetings.....21

Journal clubs	8
Conferences	11
Graduate Student Council	2

- *Participate in an interdisciplinary journal club.*
- *Participate in Graduate Student Council or another organization and take on a leadership role.*
- *Participate in Graduate Student Council.*
- *Attend conferences outside your field.*
- *Attend conferences and/or symposia outside your field.*

Group Research.....46

- *Form a subgroup focusing explicitly on coordination, cooperation, and integration.*
- *Credit is a huge issue. Not easily lumped in with the others. Developing ground rules for credit can help. A series of scenarios regarding credit and how it was handled and followed by discussion could help generate consensus on teams regarding norms for credit.*
- *Arrange regular meetings with collaborators.*
- *Interdisciplinary group projects that address complex research problems.*
- *Work with interdisciplinary colleagues to develop a glossary of common terms relevant to shared research (including variant meanings of terms by discipline).*
- *As a junior researcher in collaborative projects, practice the skill of identifying synergies among disciplines and constructively clarifying "differences that make a difference."*

Independent Research.....21

- *Identify relevant findings in own discipline.*
- *Keep current with the current literature and refer to it often.*
- *Review current grants that support research on the problem you're studying.*
- *Learn how to use digital searching tools to identify relevant methods and concepts for particular questions/problems.*
- *Revisit your research plans once a week.*
- *Learn about history and new developments in own discipline.*
- *Identify contributions individuals and teams from own discipline have made to particular questions/problems.*

Informal Conversations.....4

- *Informal student conversations.*
- *Active participation in discussions after seminars.*
- *Informal brown bag lunch discussions.*
- *Engage in informal social activities together to create greater familiarity and ease.*

Mentoring and Consulting 29

- *Have a diverse membership on your dissertation committee.*
- *Discuss results with mentor.*
- *In written work and peer discussions, practice articulating the above points; invite feedback from peers and faculty to assess competency.*
- *Need some real interdisciplinary research teams—can some be formed among graduate school advisors for the advantage of the trainees?*
- *Regular small group of student scholars guided by pair of experienced scholars from different fields, discussing trust.*
- *Meet with mentor from another discipline to review participation in interdisciplinary events.*
- *Seek feedback on science, manuscripts, and grant applications from people other than your mentor.*

Peer Assessment and Advisory.....23

- *Create a peer advisory group composed of trainees from other areas.*
- *Project development exercises that involve members scrutinizing each other's work.*
- *Engage in peer-editing review.*
- *Undergo 360-degree evaluation by peers and colleagues.*
- *Invite feedback from peers regarding one's effectiveness as an interdisciplinary collaborator.*
- *Serve as a mentor to a new student in interdisciplinary work.*
- *Mentor someone engaged in another/future interdisciplinary project.*

Presentations 42

General	23
Student teaching	12
Collaborative	7

- *Make presentations at disciplinary conferences on the nature and importance of interdisciplinary education.*
- *Present at poster sessions, internal research days, and conferences. One gains practice having conversations with strangers in other disciplines about one's work.*
- *Present case studies and project reports at conferences of interdisciplinary fields.*
- *Create a student/trainee seminar series from a variety of departments.*
- *Present work at research poster sessions.*

- *Present at broad forums such as AAAS meetings.*
- *Co-teach units of courses and training modules.*

Reading (includes independent and collaborative).....36

- *Read primary publications in a variety of disciplines.*
- *Read literature from other disciplines and demonstrate understanding of how it contributes to addressing interdisciplinary focal issue.*
- *Read more widely outside primary discipline.*
- *Read Stephen M. R. Covey's "The Speed of Trust," engage in group discussion.*
- *Read together NIH booklet on Collaboration and Team Science, which addresses conflict resolution.*

Self-Assessment/Reflection.....26

- *Keep a diary of interdisciplinary communications, with reflections on personal reactions.*
- *Conduct a personal readiness audit for engaging in collaborative IDR.*
- *Assessment of personality traits, such as MBTI or StrengthQuest.*
- *Self-assessments (MBTI, conflict style, communication style, depth of disciplinary knowledge).*
- *Take a personality and/or leadership test focused on teamwork.*
- *Develop action plan for building on strengths and addressing weaknesses.*
- *Keep a learning journal and share reflections with peers concerning one's "aha moments" and frustrations with interdisciplinary research.*

Self-Study 7

- *Become familiar with discussion of particular research questions and problems of current importance.*
- *Learn the terminology and understand the perspectives of other disciplines.*
- *Study the history and philosophy of science.*
- *Investigate opportunities for new projects that carry forward key questions and problems.*
- *Participate in online listservs devoted to IDR problem areas.*

Special Events and Workshops.....28

Brown bag lunches with invited guests	7
Panels	3
Special lectures	1
Research sessions/festivals	5
Retreats	1
Workshops	11

- *Informal brown bag lunch discussions with invited speakers (professors from various disciplines).*
- *Assemble a multidisciplinary panel to discuss point of view for one problem.*

- *Bring senior biostatisticians into mock design sessions. Most have worked across disciplines.*
- *Retreat-type meeting with a list of short- and long-term team research goals, revisit yearly to discuss progress and changes.*
- *Graduate department combined research festivals.*
- *Participate in a workshop to move toward an integrative framework.*
- *Participate in workshops to learn about relevant contributions.*
- *Plan an interdisciplinary dialogue.*

Team Projects Within Class.....38

- *Group projects with a class.*
- *Interdisciplinary team works a problem set to integrate theory and methods.*
- *Group projects with participants from different disciplines.*
- *Develop a proposal to address a problem individually, then share solutions to the same problem developed by others in an interdisciplinary class.*
- *Participate in collaborative projects.*
- *Form an interdisciplinary team in the class. Use the mirroring technique to capture each member's perceptions of own approach and then of each of the other members. Post those perceptions on flip charts and share. Note the patterns, especially the stereotypes.*
- *Working with a small multidisciplinary group, critique the assumptions brought to a specific task or issue.*
- *Include an interdisciplinary group project as a class assignment.*
- *Work as a team leader on a project or section of a project.*
- *Group projects to learn and practice this skill.*

Team Building and Team Communications Focused.....40

- *First review the nature of trust (e.g., trust of dependability, expertise, intention, etc.) and trustworthiness (Why should they trust you?). Then explore the role of trust in effective teams—it makes open sharing possible so information flows better, more risks are taken, and more creative synergies emerge.*
- *Plan an interdisciplinary dialogue.*
- *Read and discuss together literature on IDR collaboration.*
- *Active listening exercises.*
- *Practice hearing the meaning instead of the words that other person is conveying and practice listening for the opportunities for making connections with own work.*
- *Group discussions about language.*
- *Practice with listening and feedback.*
- *When doing group activities, you can assign roles to various participants, for example, facilitator, summarizer, devil's advocate, and so forth.*

Writing 49
Exercises 12

Diary/journal	2
Academic	22
Collaborative	10
Grant/proposal	3

- *Paper describing a group research process, analyzing what was done to manage conflict, feedback, and credit.*
- *Co-author a compilation of autobiographies of team members highlighting relevant perspectives.*
- *Written assignment analyzing team dynamics of group working together on interdisciplinary project.*
- *Keep a journal recording insights gained from dialogues.*
- *Develop and publish a peer-reviewed journal article with an interdisciplinary team.*
- *Write individual project autobiographies identifying contributions and changes in approach.*
- *Write about your experiences working with a team.*
- *Write abstracts.*
- *Submit manuscript to journal(s) outside one's usual field.*
- *Publish results in a variety of forms and media, for example, blogs, open access e-journals, and so forth, and publish the data in one of the archives now available.*
- *Engage in collaborative writing of an entire proposal or publication.*
- *Write and contribute section of an article.*

GRID OF COMPETENCY BY CLUSTERS can be accessed here:

https://www.surveymonkey.com/s/4collaboration_r4

Round 4

The purpose of the final Round 4 was to share the results of Round 3 and to pose three short questions. First, panelists were asked to indicate if the categories of learning activities were agreeable and/or if they had expected to see something not listed. Second, panelists were asked to provide any final recommendations or comments that they thought might be helpful in guiding academic leaders in this specific area of graduate education and training. Finally, panelists were asked if they would allow their names to be included on the participant list in an appendix in the dissertation document without attribution to any specific comments. Sixteen

panelists completed the three simple questions. Fifteen of these indicated agreement with the general categories of learning activities identified. One panelist checked "neutral."

The focus of this study was to identify competencies considered by experts to be important for effective interdisciplinary research collaboration and to identify specific graduate level learning activities that support the development of those competencies. Beyond the simple statistical measures of agreement, the panelists provided rich qualitative comments highlighting differences and also patterns, both nuanced and more pronounced, relative to deeply rooted differences in language and often disciplinary practice that often characterize interdisciplinary collaborations and can create stumbling blocks. Qualitative observations are highlighted below to show the challenges and nuances involved when developing competency statements with scholars from quite different fields and areas of expertise. These will be discussed more fully in the next chapter but the results are detailed here.

EXAMPLE 1 –Qualitative Comments for Review of Original Competency #3

Investigate hypotheses through interdisciplinary research.

(57.1% agreed important, 28.6% neutral, 14.3% disagreed important)

Round 1: Selected responses included the following statements:

- Too general a descriptor and inadequate for non-hypothesis driven research
- It's worth noting that not all disciplines "investigate hypothesis"! This language itself carries an implicit bias toward experimental and quantitative research.
- This is pretty vague. Don't we all investigate hypothesis? And thus this boils down to "do interdisciplinary research".
- It seems that hypotheses are typically tested using standardized methods such as statistical analysis. Not necessarily interdisciplinary.
- Pretty simple statement.

Round 2: Panelists received the consensus results above: and were asked to review for deletion from list. (57.1% agreed with deletion, 35.7% neutral, 7.1% disagreed). Edits were recommended but qualitative comments included:

- I am uncomfortable removing HYPOTHESES altogether because hypothesis formation is an important part of research process, especially in science.
- I assume this has something to do with the science-oriented assumption that research is to take the form of hypotheses, rather than more qualitative "explore, understand, etc." I agree that investigating hypotheses is just one sort of research.

EXAMPLE 2 – Round 2 Review of Additional Competency #16:

Understand how to effectively manage conflict, feedback and credit relative to interdisciplinary team research. (Agree 86.7%, Neutral 13.3%, Disagree 0.0%

- VERY VERY VERY important! (Panelist 3)
- Not sure if this is 'core'. (Panelist 4)

The competency statements themselves represent a somewhat micro view and are important relative to generating specific learning activities; however restricting the discussion only to the nuances of each statement could impede a broader and ultimately more useful view. A rationale for attempting to identify more global categories depicting the competencies will be addressed in connection with the final list of competencies. Two other challenges merit discussion and emerged from a review of the qualitative comments. The first involves the language used to describe competencies and the second involves the categorization of competencies.

Underscoring the challenges inherent in any attempt to describe competencies, several panelists suggested the original competencies were "outcomes" and "things to do" versus competencies. And yet, the second group also offered additional competencies that could have

been criticized as outcomes. Representative examples and comments about the original list are included below:

- Competency 4 - Draft funding proposals.
  "I think the fundamental competency here is being able to work with researchers from different disciplines – drafting proposals effectively is a measure of that competency."
- Competency 6. Advocate for interdisciplinary research.
  "Although this is of course important, in my mind this is not necessarily something that is at the same level of core competency as others since not everyone gets a chance to do this."
- Competency 8. Read journals outside his or her discipline.
  "The competency is to express interest in research in other disciplines – reading journals outside your discipline is a measure of that competency."
- Competency 12. Present interdisciplinary research.
  "I think this is an outcome not a competency."
- Competency 15 and 16. Attend scholarly presentations. Author publications.
  "Seems more to be an outcome measure not a competency."
  "Again, seems more to be an outcome measure not a competency."
- Open Comment Contribution.
  "For my taste many of the competencies in the original list appear to be outcome measures of more fundamental competencies. For example, grant writing or publishing with other disciplines is really the outcome of a project that is successful because the actors have the required competencies to engage in interdisciplinary research: such as, a broad intellectual curiosity to ask questions outside their discipline; knowledge of the strengths and weaknesses of other approaches; and the ability to work with others across disciplinary boundaries."

Beyond difficulties in describing the competencies, there were several comments made about the need for categorizing the competencies yet acknowledgement for the difficulty in knowing how best to do so. The participants in this study suggested that clustering the original competencies into three categories: conduct research, communicate, and interact with others resulted in considerable overlap and redundancies particularly between communicate and interact. Representative comments are below and are relevant to the later discussion of creating ways to communicate competency clusters in ways that bridge the disciplines and are more comprehensive.

- These categories are OK, but don't I think capture all. Why is interaction and communication separate from conduct research? Many INTD thinkers divide competencies up along individual and collective levels.
- The three categories appear correct -- they are certainly out of order. Conduct research comes last -- the team must interact and communicate before any research could be successfully conducted. The distinction between communicate and interact appears arbitrary.
- I would have only one category (communicate), which captures the competencies included under 'research' and 'interact'.
- Two factors, learning the languages others use in their work and constraining self-serving goals (i.e., being unselfish) are alluded to very obliquely in several of the competencies. I think these points might be more useful if they were made more explicit. (e.g., "collaborate...equitably" is related but not very direct.)
- All scholarly literature builds on the previous literature. This is especially challenging in interdisciplinary research for scholars need some appreciation of what different disciplines are saying before they can outline new research strategies. So it may be worthwhile to add another category of "Grounding research in the literature" which involves identifying relevant literature in different disciplines, expressing the research question(s) in ways that do not privilege any one discipline, evaluating these disciplinary literatures, and identifying strategies for achieving common ground among these.
- It seems that there is a great deal of overlap between "communicate" and "interact with others." Perhaps breaking them down as "Conceive Research Framework," "Conduct Research/Interact with Others," and "Disseminate/Validate Research Results" would work better?
- I would add a 4th category: Learning. Since most people have a disciplinary secondary education, they are ill equipped to learn outside that discipline. So, before folks can conduct interdisciplinary research, they need to learn about different disciplines.
- Would suggest that another category could be the team <-> organization interaction - while "interact with others" may encompass this, as written above - there is little/no recognition about the role of the institution in providing an environment that not only promotes but clearly supports interdisciplinary research (through policies, procedures, processes) and models it (leadership).
- But do not address leadership of such collaborations, which requires additional skills.
- There is substantial overlap between communicate and interact. You cannot interact without communicating. I believe that teaching and learning is a key competency category. You have to teach and learn from your collaborators, in self- or group-directed ways. Or you learn from material artifacts produced by their discipline (books, journals, websites). This is an informal (non-classroom) style of learning, which requires learning on the fly as needed rather than a structured acquisition of basic to more complex concepts.

When the final list of 24 competency statements was revealed, all of the 16 panelists agreed that the list was acceptable for the purpose of further identifying learning activities. Nevertheless, while one panelists noted, "They all look good. I was happy to see competencies related to teamwork and building on one another's ideas" other panelists noted a preference for clustering the competency statements to reflect only primary competencies versus outcomes, "Yes, as long as it is clear that the list is not exhaustive but includes primary competencies." " I think the list is long and somewhat redundant. Perhaps further synthesis in needed."

Conclusion

This chapter presented the results of the investigation to a) identify the individual competencies (knowledge, skills, attitudes) needed for effective disciplinary research collaboration and b) specific learning activities that facilitate the development of those competencies. The results yield important contributions to the existing research on graduate education and training efforts needed enhance the professional and career development of emerging scholars and scientists and will be discussed in greater detail in Chapter 5.

Chapter 5: Discussion

The final chapter of this dissertation includes a brief restatement of the problem and the major methodology employed to identify a) individual competencies (knowledge, skills, and attitudes) needed for effective interdisciplinary research collaboration and b) graduate level learning activities that facilitate the development of those competencies. The focus of the chapter is to provide a discussion of the results along with conclusions, recommendations and implications for future research. The results have implications for three distinct but interrelated subgroups: individual scholars and scientists in training, collaborative teams, and academic leaders and mentors. Particular attention will be given to how the results yield important insights related to the conceptual grounding of Social Cognitive Career Theory presented in Chapter 2. Complementary relevant research that supports the results as they emerged in the course of this study will also be presented. Finally, limitations of the study will be noted.

Summary of the Study Problem and Methodology

Study Problem:

Institutions of higher education have long been challenged about the relevance of graduate education and training and whether these efforts adequately prepare graduates to address real world problems (Anderson & Swazey, 1998; Brennan, 2007). In recent years, there has been an escalated sense of urgency about graduate education and training needed to prepare emerging scholars and scientists to participate effectively in interdisciplinary research collaborations (IDRC) considered critical to address global problems related to public health, the environment, and educational, political, social and economic development and sustainability. Research results indicate that these interdisciplinary research collaborations are influenced by a complex array of organizational, interpersonal and individual factors that interact in ways that either facilitate or hinder the collaborative processes and outcomes (Hall, Stokols et al., 2008). Early efforts have focused on institutional and logistical supports and even more recently on team supports (Fiore & Bedwell, 2011). Still, there remains a serious gap in the literature about individual competencies needed for effective IDRC and what specific graduate education and training activities support those competencies.

Research Question

This study examined the following research questions:

1. What are the individual competencies needed to participate in effective interdisciplinary research collaboration?
2. What are the graduate level learning activities that facilitate the development of individual competencies needed for effective participation in IDRC?

Delphi Methodology

This study employed the Delphi methodology. The Delphi technique is based on the premise that collective intelligence of non-collated experts offered anonymously enhances the understanding of emerging issues and questions for which there is not yet common understanding, extensively published information, standard practice, or empirical research (Whitehead, 2007). Consistent with standard Delphi methodology structure, four iterative survey rounds were employed to capture qualitative and quantitative consensus data from a diverse group of scholars remotely located from one another (Adler & Ziglio, 1996; Linstone & Turoff, 1975). Results of the study were presented in detail in Chapter 4 and are discussed further in this chapter.

Research Question 1- Identifying Individual Competencies (Rounds 1 & 2)

The first two rounds of this study focused on identifying the individual competencies believed by experts to be important for effective engagement in interdisciplinary research collaborations. In the first round, panelists were asked to review and give their opinions of an initial list of 17 competencies previously identified by Gebbie et al., (2008). In addition, panelists could recommend edits and deletions and could add up to 3 additional competencies they considered important but missing from the original list. Panelists also gave their opinions about the 3 categories the previous researchers employed to organize the 17 competencies: conduct research, communicate, and interact with others. The aggregated responses from Round 1 included the results of the original 17 items and 45 additional competency statements that were shared back to the group for a second round review. Consensus was considered achieved if 75% or more of the panelists agreed that the stated competency was important. The second round

review resulted in a final list of 24 competencies that served as the basis for the second research question (Rounds 3 and 4) discussed in more detail later in this chapter.

Main Conclusions and Observations from Round 1

As has been stated previously in this dissertation (Gordon, 1994), the results of a Delphi study are not necessarily expected to yield replicable results that predict the responses of a larger population or even a different Delphi panel. They are, however, intended to inform understanding of an emerging issue or problem and represent the synthesis of opinion of a specific group of experts uniquely able to address the research questions (p. 4). To that end, subsequent reviews by other experts might address the same questions yet yield somewhat different suggestions depending upon contextual considerations and even elements related to the structure of the questionnaires. Each Delphi study is reflective of the judgments of the experts assembled and should be considered in that time frame and context.

It is not especially surprising then that this group of scholars who were prompted to consider the competencies in the context of broad-based graduate education to facilitate interdisciplinary research collaboration would offer slightly different competency statements than the previous panelists who participated in the study conducted by Gebbie and her colleagues who were looking specifically at interdisciplinary research competencies for health professions trainees. In spite of the differences between the final lists of competencies, it proved invaluable to the current investigation to begin the discussion with the thoughtfully constructed framework by Gebbie et al. (2008). Working with the original list provided a meaningful frame of reference and allowed the participants to understand the language of competency statements and to more readily participate in the discussion and move toward identifying learning activities.

The results of this study both support and diverge from the previous study and in each way contribute to our understanding of individual competencies required for effective IDRC. Since 2008 more research has been conducted and there is a growing literature concerning opportunities and challenges with interdisciplinary teams and collaboration (Klein, 2010). As mentioned previously a new field of research examining the science of team science (Falk-Krzesinski et al., 2011) has also emerged and may in part have resulted in a different starting point for the current study as compared to the previous study by Gebbie et al. (2008).

In addition, ample research describes the significance of word choice in survey construction and explores how slight differences can influence responses and results (Villar & Krosnick, 2010). The wording of the initial research question in this study prompted panelists to identify individual competencies necessary for effective interdisciplinary research *collaboration.* As such this word choice used a different prompt than in the previous consensus study when panelists were asked to identify individual competencies necessary for interdisciplinary health research.

As one panelist commented, "all interdisciplinary research is not collaborative." While that is certainly true, the intent of *this* study was to explore interdisciplinary research that occurs in the context of collaboration. Given the focus of this study to examine competencies for interdisciplinary research collaboration, the use of the word collaboration was deliberate and the impact of that word choice needs to be acknowledged. Word choice may have partially accounted for the difference in the degree to which the panelists in the 2008 study emphasized research and integration competencies and the current group, while acknowledging those, also placed a greater emphasis on teamwork and collaboration skills. In addition, the greater diversity of this second group, spanning multiple disciplines and professions, and the prompt indicating

that the focus was to prepare graduate students for a *wide range of careers* may have contributed to additions that diverged from the original statements produced by a more homogenous group of health research professionals looking at preparing health researchers.

It should also be noted that the instructions for the current study emphasized that the ultimate goal of this research was to support academic and institutional leaders within the context of establishing graduate education and training for emerging scholars and scientists. The panelists offered frequent comments that showed an appreciation for this study being situated in the context of broad graduate education and preparation of students for diverse careers. To the degree that the panelists considered these questions relative to *developmental* competencies and *emerging* scholar maturity and collaboration readiness, may partially explain the prevalence of added competency items that focused on what might be considered fundamental early stage or career competencies including critical awareness of self and discipline and then critical awareness of self in relation to others.

Although the current panelists took issue with wording nuances, there was general support for the competencies on the original list that described integration of multiple methods and general communication and interaction (e.g. one panelist noted the "important work by Gebbie"). Panelist comments reflected less criticism for what was on the list than for what they believed was *missing*. The additional competencies they suggested reflect a number of soft-skills and team skills that may have been presumed in some of the original competencies but were more much more specifically articulated by the panelists in this study. The final competencies agreed by the group to be critical for IDRC clearly connect back to the theoretical and conceptual frameworks presented in the literature review in important ways that bear discussion in this chapter.

Conceptual Grounding--3 levels of analysis: individual, team and organizational

Individual

As cited previously in Chapter 2, Stokols et al. (2008, p. S106) suggest the intrapersonal collaboration readiness of emerging scholars can be gauged in part in terms of their openness to disparate disciplinary perspectives and worldviews. Similarly, O'Rourke and Crowley (2011) suggest that when differences come to light in interpersonal interactions, sometimes with highly political undertones, these may stem from factors that exist on a very personal individual level and may reflect deep-seated values and preferences, many of which the individual scholar may never have reflected upon and may not even be aware of until he or she comes into conflict in the context of a research collaboration.

The results of the first two rounds of this investigation yielded extensive references to the importance of language and worldviews and how these must be understood at quite personal and philosophical levels within the context of interdisciplinary dialogue. There were so many references to language, philosophical and disciplinary orientations, and worldviews in fact that this researcher looked again at the composition of the group to check for balancing of disciplinary backgrounds. Although it is true that four of the panelists indicated they had at least one undergraduate or master's degree in Philosophy, many more indicated undergraduate and master's degrees obtained in diverse areas including Applied Mathematics, Biochemistry (2), Biology (4), Economics (2), Mathematics, Physics and Statistics. Additionally, only one of the panelists completed a doctoral degree in Philosophy and was currently employed in an academic role grounded in that discipline. And, consistent with the Delphi methodology, even if they

contributed more qualitative comments and added competencies from the vantage point of philosophy, 75% of the group had to agree these were important in order to achieve consensus. Clearly, the reflections and suggestions of competencies recognizing the importance of self-awareness and language and deeply held intrapersonal worldviews resonated with the group.

These comments were quite pervasive and even a bit daunting in the face of the next round to identify learning activities that support those competencies. As one panelist indicated, competencies relating to intrapersonal skills, e.g. curiosity and philosophical orientations and openness may be critical but may be quite difficult to articulate into learning activities and graduate curricula. Challenging philosophical orientations and disciplinary identities is even more complicated during graduate school when as Metz (2001) suggests junior scholars are just developing a stronger sense of professional identity as is implied in the following quotation.

Fish Is Fish

Fish Is Fish (Lionni, 1970) describes a fish who is keenly interested in learning about what happens on land, but the fish cannot explore land because it can only breathe in water. It befriends a tadpole who grows into a frog and eventually goes out onto the land. The frog returns to the pond a few weeks later and reports on what he has seen. The frog describes all kinds of things like birds, cows, and people. The book shows pictures of the fish's representations of each of these descriptions: each is a fish-like form that is slightly adapted to accommodate the frog's descriptions— people are imagined to be fish who walk on their tailfins, birds are fish with wings, cows are fish with udders. This tale illustrates both the creative opportunities and dangers inherent in the fact that people construct new knowledge based on their current knowledge.

Excerpt from National Research Council. *How People Learn: Brain, Mind, Experience, and School: Expanded Edition*. Washington, DC: The National Academies Press, 2000, p.11.

In a complementary way, Lionni (1970) playfully illustrates the challenges in constructing new knowledge using prior knowledge and worldviews that may be isolated. The

results of this study suggest that the scholars engaged in this work at a high level understand the fundamental connection between critical awareness of deeply held personal beliefs and how that understanding relates to critical competencies for effective interdisciplinary research collaboration. Issues related to misunderstandings based on differing philosophical and disciplinary orientations are evident in the literature (Eigenbrode et al., 2007: Reich & Reich, 2006) and were also mentioned in this study as sources of collaboration dysfunction and conflict. Though a challenge, the subsequent survey format in Round 3 required that each competency be matched with learning activities and forced panelists not to gloss over these harder to describe competencies in identifying helpful learning activities. Those results will be discussed in regard to the second research question.

There is a subtle but direct relationship between the results relating to the question of defining individual competencies that are affected by deeply held personal values and beliefs and grounding offered by Bandura (1977; 1986) who conceptualized social foundations of thoughts and action in the social learning theory, which serves as the theoretical basis for social cognitive theory. Detailed in chapter two, Bandura's theories articulate the extensively researched framework that holds that any account of the determinants of human action must include self-generated influences as a contributing factor and must be considered within the reciprocal causation of action (behavior), cognitive, affective and other personal factors, and environmental events (Bandura, 1986, p.1176). Human development, adaptation, and change are all framed in social cognitive theory as involving three distinct modes of agency: personal, collective and proxy agency with the most central being self-efficacy beliefs that are influenced by personal performance experiences that can either enhance or hinder future self-efficacy and outcome expectations.

Also relevant to the discussion of these results is Lent, Brown, and Hackett's (1994) social cognitive career theory (SCCT) that extends Bandura's (1986) general theory and contributes to the discussion of how people form interests, make choices, and accomplish academic and occupational success. They contend that self-efficacy, outcome expectations, and goals combine with environmental and contextual barriers and supports in ways that either facilitate or hinder success (Lent, Brown, & Hackett, 2000, p. 36). Deeply held personal values and beliefs are carried by each individual into the context of interdisciplinary research collaborations and when not well-understood at a personal level, the challenges for understanding one's own and other's orientations in the context of teamwork become quite difficult. When interactions become strained, the collective-efficacy of the group is negatively affected (i.e., outcome expectations become negative) but so is the fundamental self-efficacy that emerging scholars and scientists carry into the next collaboration. For example, one might conclude that it is too difficult to work within interdisciplinary teams and that he or she is not competent at tasks related to interdisciplinary research activity. Thus, it is not just in the inevitable risk of seeing the world in a limited way as depicted in Leoni's children's tale that is concerning or that poor self-efficacy may be experienced by the individual scholar, but rather how those limitations may contribute to poor collective efficacy and even conflict and distress in collaborative groups and thereby disrupt the scholarship and discovery process altogether (Hicks & Katz, 1996; Kezar, 2005).

Team

The second major contribution from the group of scholars who participated in the current study relates to the addition of more clearly articulated individual competencies explicitly connected to *team skills*. More specifically, team skills, building trust, managing conflicts, and

developing shared vision were novel when compared to the original list and were highly rated by the panelists as evidenced by the fact that they appear in the list of final competencies. These insights relate back to the important work by Fiore (2008) and by Bennett et al., (2010) who argue it is important to connect teamwork principles and trust building exercises into efforts to improve interdisciplinary research collaborative practice. Many of the suggested intrapersonal competencies, including self-critique and reflection of strengths and weaknesses were described within the context of team functioning. The importance of individual competencies relating to team functioning can be seen in the subsequently identified learning activities, many of which are offered in the context of team projects and team building exercises.

Organization

Preparing individuals to function effectively within the context of teams presents many challenges for academic leaders and their organizations. Crowley et al. (2010) suggest part of that preparation involves helping scholars to better understand their own beliefs and values as they also seek to understand the beliefs and values of others, which may be quite different from their own. Becher (1989) argues communicating and collaborating across discipline boundary lines is similar to communicating with those from other less familiar cultures. Although interdisciplinary research cultures may be a goal within some institutions, Silver (2003) contends that institutions do not have a culture but rather are made up of many subcultures. Efforts to build interdisciplinary research cultures must consider those subcultures.

The results of this study support Silver's (2003) argument and suggest academic leaders need to look deeper than just across the surface of disciplinary differences and consider how different individuals even within disciplines approach collaborative work. Some individual competencies like openness and broad intellectual curiosity are more difficult to observe,

measure, and facilitate than others. Panelists commented that many of the original competencies were merely statements of "things to do" and offered that we seem to have language for things to do and things to know but less clarity about how to capture attitudinal competencies.

The results of this study highlight individual competencies in relation to interdisciplinary collaborations within the organizational context of graduate education and training. For the purpose of this discussion it is important to look at the nature of the strong patterns and themes that emerged from the qualitative comments and from the additional competencies suggested by the group of scholars in the current study given the group's disciplinary diversity (highlighted in Chapter 4). The value of a Delphi study cannot only be that it reflects expert opinion of nuanced wording at a point in time. The consensus opinions presumably yield insights that inform practice and conceptual understandings better than singular and independent efforts. So, while it would perhaps not be surprising that another group would take issue with the exact wording of the new list of 24 competencies, at this point it is especially useful to consider what the additional competencies contribute to what we need to know about graduate education and training.

Relationship of the Current Study to Learning Outcome Research

Borrego and Newswander (2010) conducted an examination of interdisciplinary studies (humanities) literature *and* content analysis of 129 proposals successfully submitted primarily by science and engineering faculty to secure Integrative Graduate Education and Research Traineeship (IGERT) program funding. Through their independent analysis, they noted five categories of *learning outcomes* for interdisciplinary graduate education articulated in those proposals: 1) disciplinary grounding, b) integration, c) teamwork, d) communication, and e)

critical awareness (p. 80). In a related study, Borrego and Cutler (2010) performed content analysis on 130 funded IGERT proposals to examine, from an instructional design framework, what desired outcomes, evidence, and learning experiences are currently associated with interdisciplinary graduate education and to what extent these components are aligned. Though from a slightly different perspective, these two recent research efforts provide a useful framework for also considering the individual competencies that emerged from this investigation.

A premise of this study is that within the context of graduate education, learning activities should be developed and aligned with the intention of facilitating critical individual competencies. By extension, it is expected that these learning activities would be consistent with the overall learning outcome goals of graduate education and training programs that more broadly claim to facilitate interdisciplinary research and education for groups of individuals. In fact, a critical view of the emergent individual competency statements from this study when viewed in the context of Borrego and Newswanders's (2010) findings indicates that at least the language for describing *outcomes* which they found and the language which the group of scholars in the current study used to identify individual *competencies* are aligned. Although the relationship should be qualified as the investigations were conducted independently, the alignment does suggest a helpful framework for future considerations regarding curriculum development.

The five categories of learning outcomes identified by Borrego and Newswander (2010) might also be considered useful in considering individual competencies and issues related to temporal progression of maturity and development of the individual scholar, e.g. does disciplinary grounding need to be fundamentally secure prior to integration. This is not to

suggest that the development of individual competencies occurs in a strictly linear manner but simply recognizes that some competencies and activities may be prioritized in a particular sequence in relation to others. In looking at the original list of competencies, integration and communication and possibly disciplinary grounding most closely capture the 17 original items whereas the new items offered might best be categorized as adding to the list in the arena of critical awareness (of self and others) and teamwork. Applying Borrego and Newswander's (2010) framework of learning outcomes offers another way to understand the competency statements without getting lost in the nuance of each word. Both the macro and micro views are important.

Implications for Future Research

Relative scaling of the 24 competency statements was not attempted in this study; however, in the future it may be helpful to consider which of these competencies are most critical and whether or not some presuppose others. As noted, reflection on the sequencing of efforts to facilitate the competencies may also be useful. Incoming students' individual competencies for IDRC vary greatly within the same graduate programs and future research should explore ways to provide the individual scholar and mentors with a reference point for where they are developmentally relative to IDRC competencies. As presented in great detail in *How People Learn: Brain, Mind, Experience, and School*, there is a great deal of literature and evidence that argues that learning is enhanced when educators are familiar with the knowledge and beliefs that students carry into their classrooms so that they (the educators) can have a sense of where to begin and also how to assess learning progress (p. 11).

Efforts by Olson et al. (2008) already exist to help teams gauge collaboration readiness. Development of a collaboration readiness instrument focused on the individual scholar could

further provide the scholars and mentors with guidance for establishing training and development priorities and sequencing learning activities. Identifying where students are at the beginning of facilitative efforts and then assessing their progress can provide evaluative data to make improvements to any curricular interventions but again requires the development of instruments to assess and evaluate.

There is considerable merit in the proposal to "further synthesize" and consolidate the competency statements as one panelist suggested. Although the final list of 24 competency statements has already been consolidated from 62 statements (17 original plus 45 additional) it would be useful to incorporate the expertise of competency language scholars to looks at ways to capture the essence of each competency in language that is most helpful in terms of curriculum development that aligns learning objectives for individuals and groups to learning activities and outcomes.

Kara Hall, Director of the Science of Team Science (SciTS) Team, Co-Director of the Theories Project, and Health Scientist at the National Cancer Institute provided a thoughtful post-study review of the list of 24 competency statements and suggested the following broad categories for grouping and conceptualizing the specific competency statements:

- Intrapersonal Competencies
- Disciplinary Awareness and Exchange
- Processes of Integration
- Teamwork, Management, Leadership
- Competencies of Fruition

The groupings provided by K. L. Hall (personal communication, February 9, 2013) were welcomed by the researcher and will be incorporated into the language of future studies. For a breakdown of the specific groupings of the 24 competency statements, please see Appendix I.

Research Question 2

Learning Activities that Facilitate the Identified Competencies

Review of Results of Research Question 2

The final list of 24 competency statements was presented to the group of panelists in Round 3. This final list included the aggregated competencies that achieved 75% panelist agreement in Round 2 as being important for effective interdisciplinary research collaboration. In Round 3, panelists were asked to identify up to 3 specific graduate level learning activities for each of the 24 competencies. As was the case with the previous round, this third survey was quite time-consuming and required a clear commitment on the part of the panelists to complete. Prior to identifying learning activities, the panelists were asked to validate the list of competency statements. Sixteen panelists began the survey and all indicated agreement with the final list. Twelve panelists completed all of the items requested. Finally, 16 panelists completed the fourth round. This final round was to simply share back the aggregated results of the third round and to gather any final qualitative comments.

As with any Delphi study, the time and commitment that is required of panelists can be quite burdensome and the current examination was not an exception. The second round was due just before the Thanksgiving holiday, the third round was due just prior to the winter holiday and the fourth and final round shortly after the New Year began. One panelist, who completed each

item in great detail and commented on the importance of the study, nevertheless remarked how "tedious" the project was. Another questioned the need to identify learning activities for each of the competencies versus being able to give more general responses. A fourth wondered why they could not just offer a few "rich examples." A fifth panelist navigated a transatlantic move between Rounds 3 and 4. Nonetheless, the panelists offered many qualitative comments and 471 uniquely identified learning activities were grouped by competency and by cluster (type of activity). As mentioned previously, some activities were considerably detailed and warranted inclusion in two categories.

Panelists were provided the following open-ended prompt:

> For each competency, please list up to 3 **learning activities** at the graduate student level, that you consider helpful for facilitating the development of that specific competency. Please try to be as direct and concise as possible in linking the suggested activity with the competency.
>
> For the purpose of this study **learning activities** may be **broadly defined** and *may range from highly formal and structured activities, to more informal and non-structured activities.* The idea is to generate suggestions and options for graduate student mentors and academic leaders who may be from very different institutions and are considering a host of options that support graduate education in this area.

The responses varied greatly in the level of specificity and detail shared. Some panelists apparently more familiar with competency-based curriculum development and/or those actively engaged in structured graduate training and education efforts were able to offer quite detailed examples whereas some of the others, engaged in high level interdisciplinary research collaborations but not familiar with the terminology of competencies and curriculum development often offered more general or nuanced examples. For example, while one panelist suggested "case study" as a learning activity, another offered a specific example of a case study,

(e.g. "Provide a short but complex case scenario, ask a small, perhaps interdisciplinary, group to look at it from multiple disciplinary angles and perhaps come up with the combined solution. Maybe even provide a framework to scaffold their discovery of multiple differing perspectives, their utility and possible complementarity"). Similarly, while one panelist suggested "work on a mock project together in coursework", another offered a more detailed, "Form an interdisciplinary team in the class. Use the mirroring technique to capture each member's perception of own approach and then of each of the other members. Post those perceptions on flip charts and share. Note the patterns, especially the stereotypes."

Identification of Clusters

At this level of analysis, in order to blind code the items all of the responses were reviewed independently from the panelist's identity being known. Typical for qualitative research, all of the responses were reviewed extensively and patterns and themes were identified through a constant-comparison methodology (Corbin & Strauss 1990). Initially a framework for learning activities was identified in the literature and selective coding was considered, however, when it was clear that using that framework resulted in the data being forced into the categories the selective coding methodology was abandoned in favor of open coding described by Glaser (1992) so that the emergent activity clusters were more appropriately identified from the actual data. An independent professor of education then reviewed the coding protocol and the cluster decisions to provide a separate integrity check.

The clusters that were identified overall and the learning activities that were associated with each of the individual competencies offer distinct patterns and merit discussion in the context of the following: a) individual competency development, collaboration readiness and graduate preparation b) interdisciplinary team collaborations and readiness and c) organizational

readiness and support for graduate education initiatives that require varying degrees of facilitation, coordination and structure. Consistent with the recurring themes identified throughout this research investigation, each of these groups is independent and yet critically interrelated.

As presented in more detail in Chapter Four, eighteen distinct clusters of learning activities were identified and include the following with the number of associated items included in parenthesis: coursework (66) with subcategory graduate seminar (23 of the 66), academic writing-individual and group (49), group research (46), presentations and student teaching (42), team building and communications (40), team projects (38), reading (36), mentoring and consulting (29), self-assessment and reflection (26), case studies (24), peer advisory (23), formal meetings (21), independent research (21), special events (17), workshops (11), self-study (7), and informal meetings (4).

Rhoten (2004, p. 6) cautions about patchwork approaches toward interdisciplinary collaboration the results of which may be "incoherent." A common criticism voiced in the literature is that there is much discussion about interdisciplinary research and collaboration but not a lot that qualifies as focused and structured support (Rhoten & Pfirman, 2007). In the current study, the majority of suggested activities to facilitate interdisciplinary research collaboration competencies fell into the combined and quite structured learning activities that make up the coursework and graduate seminar cluster (66). Graduate seminars are a particular type of formal course but because they were specifically named 23 times, they are identified as a sub-category of the coursework cluster.

The remaining suggestions were heavily weighted toward experiential learning activities whereby graduate students would be able to "practice, practice, practice" and "learn and then do"

within the context of group research and team projects. These activities focused on allowing the graduate students to practice teamwork and communications either in student presentations, student teaching or team projects and teambuilding and made up the majority of the recommendations provided. Again, these types of suggested learning activities require some degree of structure and pre-planning and as suggested are meant to be facilitated and guided by mentor scholars and scientists, advisors, instructors and in a few suggested examples, peer-mentors within a social learning context.

Conceptual Grounding - Activities and Clusters

The structured and social learning context that characterize the results that emerged from round 3 warrant additional discussion relative to Bandura's (1997) social learning theory and social cognitive theory (1986) previously described in chapter two and also in reference to the first research question results about the competency statements. Recall that Bandura's (1977) social learning theory argues that learning occurs in the context of a social environment whereby people can learn through observational modeling, that internal mental states play a critical role in the process and that learning does not always lead to a change in behavior (1977). Bandura (1977) argues that the modeling process requires: attention, retention, reproduction, and motivation and that performance success experiences are critical to the development of positive self-efficacy. As such Bandura's framework is consistent with the nature of the majority of learning activities recommended and does provide important contextual considerations in efforts to develop the competencies scholars and scientists will need for effective IDRC.

Likewise, research by Social Cognitive Career Theorists like Lent, Hackett and Brown (2002) who extend Bandura's (1997) work is again useful for grounding the suggested learning activities and to further frame how cognitive elements interact with context-sensitive barriers and

supports. Understanding these can guide career and experiential learning interventions. If carefully designed and facilitated, early success experiences in interdisciplinary research collaboration can set the course for future effectiveness by contributing to positive self-efficacy and positive outcome expectations. The expert panelists in this study recommend focused and facilitated learning activities rather than expecting students to figure this work out intuitively as Larson, Cohen, et al. (2011) caution is shortsighted.

In addition to a clearly identifiable link to social cognitive learning theories, and especially given the graduate level of scholarship and science expected, the results recommending facilitated instruction and discussions should also be considered in the context of constructivist learning theories influenced by Vygotsky (1978). As explained by Mayer (1992) constructivist learning theorists argue that learning occurs when a student actively constructs or creates his or her own knowledge in a process of sense-making that is highly individualized and influenced by prior knowledge and mental models (p.143). It is important here to acknowledge a common misunderstanding regarding constructivist theories of knowing as further discussed in by Bransford, Brown and Cocking (2000) in How People Learn: Brain, Mind, Experience, and School:

> A common misconception regarding "constructivist" theories of knowing (that existing knowledge is used to build new knowledge) is that teachers should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves. This perspective confuses a theory of pedagogy (teaching) with a theory of knowing. (p. 11)

Mayer (1992) challenges the misconception and argues that learners can construct meaning in ways consistent with constructivist learning theories, even in situations of

well-designed instruction. The comments and suggestions by scholars in this study offer recommendations that are consistent with both the social learning and constructivist theories of learning and take into consideration the many dimensions of competencies including prior knowledge, skills and attitudes that students bring into interdisciplinary research collaborations.

As noted, most of the suggested learning activities were fairly structured. Conversely and to the surprise of the researcher, there were relatively few suggested activities categorized as informal meetings, such as social gatherings (7) and self-study (4). Those describing informal social activities were quite general in description, e.g. "informal social gatherings" and those involving self-study tended to relate more to the disciplinary grounding at the individual level that panelists commented is a necessary precursor for effective contributions to team interactions.

Learning activities were identified for all of the competencies and there was a frequency range of suggestions from 9 to 34 per competency statement. However, as one panelist wrote, "Most of the interdisciplinary activities that I do address multiple competencies. It is NOT as though one comes up with a different activity for every individual competency."

Implications for Practice

The results show a strong preference for structured (facilitated) versus non-structured activities and for team based versus independent learning activities as important for facilitating IDRC competencies. This has practical implications for young scholars and scientists exploring various graduate study options and for academic leaders dedicated to providing effective best practices in this area. Although the suggested activities for each competency statement were presented in Chapter Four, the value of these suggested activities would be best understood by

seeing how they are *integrated* within the context of a thoughtfully constructed curriculum rather than by further fragmentation of the data.

We know from recent literature (Borrego & Cutler, 2010; Borrego & Newswander, 2010) that the language that articulates desired interdisciplinary program outcomes is consistent with the language the experts in this study employed to describe necessary individual competencies and supportive learning activities. Yet, the alignment needs to be in more than in the descriptive language of competencies and outcomes alone. Nerad and Cerney's (2000) survey of more than 6,000 Ph.D. alumni provides evidence that teamwork, collaboration, interdisciplinary work, and organizational and managerial skills are required in a variety of post-graduate careers and settings but less than 20% of the survey respondents reported having had graduate experiences that supported those skills. This gap identified by other scholars including Gaff (2002, p. 12) between the practical focus of doctoral programs and the work actually expected of doctoral program alumni whether in the academy or other institutions is particularly troubling in light of the results of this study that indicate experts believe these are the kinds of experiences that will lead to more effective interdisciplinary research collaborations.

Graduate education that seeks to promote interdisciplinary research collaboration competence requires both an understanding of what competencies graduate students need to have and learn *and* how they will develop and learn those competencies. At the critical center of these efforts are opportunities for students to participate in carefully guided learning experiences in the context of interdisciplinary student teamwork as described by the panelists in the current study. This will require that academic leaders who value enhancing a culture of interdisciplinary research, take a deliberate and focused approach to developing education and training curricula

or run the risk of offering what Rhoten (2004) suggests are "piecemeal, incoherent, catch-as-catch" efforts.

Mentors will need to address the question of what supports *to offer* and how to offer them. Graduate students would also do well to assess what kinds of supports they will *be offered.* Related to this and because of the critical context of teamwork, a student's opportunities to participate with other scholars across disciplinary boundaries will vary from institution to institution and need to be evaluated as well. Many factors contribute to a prospective student's choice to attend a particular graduate school. Meaningful opportunities to develop interdisciplinary research collaboration competencies needed to support the transition to post-graduation careers will likely become increasingly important and should be scrutinized as part of the graduate school enrollment decision-making process.

Limitations of the Study

There were several limitations that need to be acknowledged here so that they can be considered in future research. Consistent with Delphi methodology, the panel of experts was composed of a small group of experts recognized for their interdisciplinary scholarship and graduate education leadership at an exceptional level. As such their comments and insights reflect and presume the importance of a collaboration ethic that may or may not be representative of many academic leaders and graduate student mentors. The survey instrument and four iterative rounds were time consuming and tedious and as a result the questions needed to be carefully scripted and contrained to the original research. Efforts to further examine how to coordinate and implement these activities in the context of a well constructed curriculum is necessary but was beyond the scope of this initial investigation. Logistical and practical factors including financial resources, staffing supports, and environment and space considerations were

not considered but need to be relative to identifying how different organizations can assess the feasibility of offering learning activities within their unique institutions.

Graduate Training and Education and Implications for Future Research

The goal is not IDRC; the goal is better science and scholarship that may be enhanced by IDRC. It is clear that this work is important, yet quite challenging in the face of the complexity of many interacting individual, interpersonal and organizational elements. This investigation represents a specific and even interdisciplinary view of issues and challenges for graduate training and development of scientists and scholars in the specific context of preparation for interdisciplinary research collaborations. Although this study was not rooted in a traditional framework of curriculum and instruction the next challenge will be to determine how to further connect the interdisciplinary expertise of many different practitioners, including those with subject matter expertise and those with experience in instructional design, career development and guidance, and educational program development and implementation to further frame and map best practices that link the competencies and learning activities identified here to some integrated curriculum with clearly aligned learning outcomes.

As one participant noted one of the biggest challenges with the results of this examination will be to transfer the wisdom of the experts into a framework that is workable not only for those wanting to finesse programs currently in place but most importantly to provide guidance to academic leaders and groups at the beginning stages of this work. Another panelist offered, "This project is a good idea. The challenge is enormous. It will take decades to solve it. This project can move the process forward." For independent graduate students and those academic leaders who may be struggling at the beginning stages of this work in an ever competitive and complex environment of higher education, practical guidance may be what is most needed. It is one thing

to know what competencies are important and what activities facilitate those competencies and how these relate to the overall learning objective but understanding how to develop and implement an integrated curriculum given institutional and contextual factors will be needed for successfully translating this work to practice.

The scholars in this study shared a variety of learning activities that support the specific competencies they considered necessary. These learning activities must, however, connect back to a broader curriculum and additional research is needed to provide that connection. Course syllabi, team project examples and case studies exist currently to support this work and have been offered preliminarily in the course of this study. These need to be framed in a curriculum guide with a more integrated thoughtful collection of examples, case studies, activities, and instructional supports. Attention in any field guide will also need to address the institutional resources needed along with the challenges and hurdles that might occur so that diverse leaders in a variety of institutional settings with varying levels of resources and staffing can understand best practices and can evaluate those for feasibility and desirability relative to their independent institutional resources, commitment, timing and structure.

As mentioned previously, it is recommended that additional research is needed to support the individual scholar in identifying and assessing graduate student environments as well as assessing his or her own independent collaboration readiness. Future research related to curriculum mapping can complement the individual scholar's journey. While some developmental activities can support individual scholars at the beginning of their graduate school experience, still others can be enlisted to support new teams at the pre-collaboration and collaboration stages.

Harden (2000) offers a framework for curriculum planning and evaluation employed in the context of medical education that may prove useful to scholars attempting to design graduate education curricula. Using the metaphor of a ladder, Harden presents the 'integration ladder' as a way of organizing structure and curriculum discussions and planning that move along a continuum of practice from isolation of disciplines at the bottom of the ladder through awareness, harmonizing, nesting, temporal coordination, sharing, correlation, complementary, multi-disciplinary, interdisciplinary and finally transdisciplinary integration at the top (p 551). Just as some assessment of where individual students are relative to their collaboration readiness, future research is needed to help academic leaders thoughtfully consider their relative starting places on the ladder in light of goals and resources.

Conclusion

Michael M. Crow, President of Arizona State University provided the keynote address, *How to make it work in real time and real life: building interdisciplinary programs*, at the National Research Council planning meeting on interdisciplinary science teams at the National Academy of Sciences (January 11, 2013). Crow, who is recognized for his innovative and non-traditional leadership at Arizona State, offered two critical observations that relate directly to the results of this study. In his response to the question, *how do individual factors, e.g. openness to divergent ideas, influence team dynamics success (e.g. cohesion)?* Crow offered the following: "On a scale of 0 to 10, individual factors, i.e. the individual person, the individual actor, the individual actors involved in the team science, I weight this 9 out of 10—it is among the singularly most important factors." Secondly, Crow encouraged the group assembled to recognize that facilitating this work goes beyond simply understanding the self-reflective, inner workings of the individual and requires deliberate, focused conceptualization of architecturally

oriented design of graduate science and scholarship education (January 11, 2013, National Academy of Sciences).

There is an urgent need for relevant graduate education and training to prepare emerging scholars and scientists to participate effectively in interdisciplinary research collaborations in a variety of professions and institutions upon graduation. Interdisciplinary research collaborations are at the center of efforts to address the most pressing and complex problems affecting our global community. While individuals and teams are at the core of those collaborations, academic leaders within the context of higher education have a particular role and responsibility in developing and providing meaningful educational opportunities that facilitate the development of critical research collaboration competencies.

This examination leveraged the collective wisdom of an exceptional group of scholars with expertise in both interdisciplinary research collaborations and graduate student mentoring. The results of this study address gaps in the literature and more clearly articulate a) individual competencies (knowledge, skills and attitudes) needed for effective interdisciplinary research collaborations and b) specific learning activities that support the development of those competencies at the graduate student level. The results of this study will assist academic leaders and individual scholars attempting to identify key supports needed when preparing scholars and scientists for post-graduate careers that will inevitably involve interdisciplinary collaboration.

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Appendix A: Prospective Panelist Sources

Potential panelists identified through:

- Review of literature;
- Review of conference presenter listings;
- Search of national and international conferences and committees (including Facilitating Interdisciplinary Research and Education Symposium group, University of Colorado, Boulder, 2011, and Science of Team Science conference, Northwestern University, Chicago, 2012);
- National and international organizational membership for National Organization of Research Professionals (NORDP), Northwestern University Clinical and Translational Sciences (NUCATS) Institute, NIH Science of Team Science (SciTS) ;
- Recommendations from NIH Office of the Ombudsman.

For the purposes of this study, experts met the following criteria:

1. Noted scholarship in area(s) of interdisciplinary research collaboration with record of achievement as measured by publications, peer review, conference proceedings, and other activities and as approved for participation by panel of advisors;
2. Distinguished record of scholarship (publications/awards), including interdisciplinary research;
3. Earned doctorate;
4. Past or present service in graduate advising/mentoring role;

Additional demographic information will be collected on each expert and will include gender, country of residence, discipline, and years of experience.

Appendix B: Delphi Email Confirmation EXAMPLE

Dear (Name of Expert Panelist),

Thank you for accepting the invitation to participate in a study to identify: a) **competencies** needed for effective interdisciplinary research collaboration and b) **graduate-level learning activities** that facilitate the development of those competencies.

The study was designed to accommodate the schedules of distinguished scholars and researchers participating from several different institutions and countries.

Round 1 of the study will take approximately 20 minutes to complete.
The survey can be accessed at (personalized link inserted here)

Please submit your responses as soon as possible but not later than Friday, October 19, 2012.

The structure of survey rounds is summarized below. There will be approximately 4 weeks between each round.

Round 1. Edit initial list of competencies. (Survey link is above.)
Round 2. Review and respond to aggregated list of competencies.
Round 3. Identify graduate level learning activities that support the development of the specific competencies that were identified in Round 1 and that received group consensus in Round 2.
Round 4. Review and respond to aggregated lists from Round 3.

Final Report. Summary of findings and final report.

Thank you again for your willingness to participate in this study. The insights and practical recommendations gathered in this study will be shared with the intent of inspiring meaningful graduate education activities that promote the interdisciplinary research collaboration competence of emerging scholars and scientists.

With respect and appreciation,
Valerie

Valerie Ciocca Holt, M.B.A., M.Ed.
Lehigh University, Bethlehem, PA

Appendix C: Informed Consent Form

LEHIGH UNIVERSITY

Implied Informed Consent Form for Social Science Research
Lehigh University

Introduction

I hereby agree to participate as a subject in the research project on **"Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Strategies"** conducted by Valerie C. Holt.

It has been explained to me that the purpose of the study is to identify the a) competencies (combinations of knowledge, skills, and attitudes) needed for effective interdisciplinary research collaboration and b) graduate education activities that facilitate the development of the identified competencies.

Procedures

The investigation will employ an iterative Delphi survey methodology.
Phase I. Participants will be provided a list of 17 core competencies previously identified by Gebbie et al.(2008) as being necessary for effective research collaboration. Participants will rate level of agreement with the identified list and will also edit and add to or delete items previously identified. The questionnaire consists of 17 competencies and will take approximately 20 minutes or less.
Phase II. Participants will be asked to identify specific learning activities that facilitate the development of those agreed upon competencies.

Risks/Discomforts and Benefits and Compensation

Risks are minimal for involvement in this study. There are no direct benefits for participants. However, it is hoped that through participation, researchers and practitioners will learn more about competencies needed for effective interdisciplinary research collaboration and graduate student learning activities that facilitate the development of those competencies. There is no compensation for participation.

Confidentiality

All data obtained from participants will be kept confidential and will only be reported in an aggregate format. All questionnaires will be concealed, and no one other than then primary investigator and assistant researcher listed below will have access to them.

Participation

Completion and return of the survey implies that you have read the information in this form and consent to take part in the research. Please print and keep this form for your records or future reference. Your participation is entirely voluntary. You may withdraw at any time, and you may decline to answer specific questions. You have the right to withdraw at anytime or refuse to participate entirely. If you desire to withdraw, please close your internet browser and notify the principal investigator at this email: vah2@lehigh.edu.

Questions about the Research

If you have questions regarding this study, you may contact Valerie C. Holt, at 484-264-8274, vah2@lehigh.edu

Questions about your Rights as Research Participants

If you have questions you do not feel comfortable asking the researcher, you may contact Dr. Jill Sperandio, jjis204@psu.edu or 610-759-3392, or Susan Disidore at Lehigh University's Office of Research and Sponsored Programs at (610) 758-3020 or sus5@lehigh.edu

Please click the **Next** button below to respond to the survey.

Appendix D: Survey Round 1

Round 1: Questionnaire

Background:
The purpose of this research study is to identify core competencies required for effective interdisciplinary research collaboration and to identify specific learning activities that facilitate the development of those competencies.
The study results will provide practical guidance to academic leaders and graduate educators engaged in preparing emerging scholars and scientists for a broad range of post-graduate careers that require interdisciplinary research collaboration competence.

Definition of Competency:
According to Parry (1996), competency refers to

> a cluster of related knowledge, skills, and attitudes that affect a major part of one's job (a role or responsibility), that correlates with performance on the job, that can be measured against some accepted standards, and that can be improved via training and development. (p. 50)

The 17 Competencies for Interdisciplinary Researchers:
In an earlier Delphi study, Gebbie et al., (2008) identified 17 observable competencies as necessary for interdisciplinary health research. These 17 competencies will serve as an *initial* framework for discussion though are not intended to be restrictive as the results of this study and the identified learning activities are proposed for a broad range of scholarly careers requiring interdisciplinary research competence.

These previously identified competencies are broadly categorized into three main clusters as follows:

Conduct research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks
2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary rese protocols
3. Investigate hypotheses through interdisciplinary research
4. Draft funding proposals for interdisciplinary research programs in partnership with scholars other disciplines
5. Disseminate interdisciplinary research results both within and outside his or her discipline

Communicate

6. Advocate interdisciplinary research in developing initiatives within a substantive area of stu
7. Express respect for the perspectives of other disciplines
8. Read journals outside his or her discipline
9. Communicate regularly with scholars from multiple disciplines
10. Share research from his or her discipline in language meaningful to an interdisciplinary tea
11. Modify his or her own work or research agenda as a result of interactions with colleagues f fields other than his or her own
12. Present interdisciplinary research at venues representing more than one discipline

Interact with others

13. Engage colleagues from other disciplines to gain their perspectives on research problems
14. Interact in training exercises with scholars from other disciplines
15. Attend scholarly presentations by members of other disciplines
16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks
17. Author publications with scholars from other disciplines

Appendices E-G: Surveys

Each of the surveys is appended to this document and may be accessed here for electronic review just as panelists accessed and completed online.

Round 1. https://www.surveymonkey.com/s/4collaboration?c=68

Review and validation of list of competencies compiled by Gebbie et al., (2008).

Identification of additional competencies considered critical for effective IDRC.

Round 2. https://www.surveymonkey.com/s/4collaboration_r2?c=68

Participants review results of round 1 and indicate opinions of *suggested additions.*

Round 3. https://www.surveymonkey.com/s/4collaboration_r3?c=68

Participants validate consolidated list of competencies from Round 2 and identify learning activities specific to each agreed upon competency.

Round 4. https://www.surveymonkey.com/s/4collaboration_r4

Participants review results from Round 3, offer final qualitative comments.

Appendix I

- Intrapersonal Competencies
  - Demonstrate broad intellectual curiosity to ask questions across disciplines
  - Maintain an open mind in order to clearly hear perspectives of others during explorative interdisciplinary dialogues
  - Recognize personal strengths and weaknesses as related to interdisciplinary research collaboration
  - Subject own disciplinary discovery to interpretation and scrutiny by researchers from other disciplines
  - Understand how own expertise can contribute to addressing a problem and how that differs from the contributions of others in interdisciplinary collaborations

- Disciplinary Awareness and Exchange
  - Demonstrate critical awareness of the underlying assumptions of own discipline, its scope and contribution and limitations in addressing a given research question
  - Evaluate the assumptions and limitations of all disciplines in interdisciplinary collaborative initiatives
  - Engage colleagues from other disciplines to gain their perspectives on research problems, themes or topics
  - Share research from own area of expertise in language meaningful to an interdisciplinary team

- Processes of Integration
  - Collaborate with others to integrate theories, methods and insights of multiple disciplines to improve understanding of problem or issue
  - Develop interdisciplinary research framework(s) in collaboration with scholars from other disciplines
  - Develop a shared interdisciplinary vision with collaborators, communicate it effectively, and revisit it at regular intervals to determine if changes are required
  - Modify own work or research agenda as a result of interactions with colleagues from fields other than own
  - Integrate concepts and methods from multiple disciplines in designing research protocols

- Teamwork, Management, Leadership
  - Build trust among collaborators in an interdisciplinary team
  - Understand strategies for interdisciplinary teamwork and communication including clarifying the meanings of key concepts and appreciating the perspectives of other disciplines
  - Develop team skills in order to strengthen team structure and dynamics
  - Build skills for team facilitation and leadership
  - Understand and effectively manage conflict, feedback and credit relative to interdisciplinary team research
  - Contribute to the creation of collective interdisciplinary knowledge that includes: thinking with team, adapting individual contributions, trusting value of other contributors, and negotiating differences

- Competencies of Fruition
  - Contribute to a variety of educational initiatives with scholars from other disciplines, e.g. seminars, conferences, scholarly presentations, and research symposia
  - Present interdisciplinary research at venues representing more than one discipline
  - Disseminate interdisciplinary research results to various audiences in multiple disciplines
  - Draft research proposals and author publications in partnership with scholars from other disciplines

Final List of 24 Competencies Validated by Expert Panelists and Employed in Round 3.

Grouping of Competencies by Kara Hall, Director NIH/NCI Science of Team Science Project.
K. L. Hall (personal communication, February 9, 2013)

Vita

Valerie C. Holt

484-264-8274
val.holt@me.com

EDUCATION:

Lehigh University, Bethlehem, PA 18015
College of Education
Ed.D. Educational Leadership. Successful Defense: February 25, 2013 Degree Conferred: May 20, 2013
Dissertation Title: *Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Activities*

Doctoral Coursework:

Organizational Leadership & Development
Professional Development and Supervision
Applied Learning Theory
Statistics
Evidence-Based Decision Making
Public School Law
Doctoral Research
Ethical Leadership and Decision Making
Program Evaluation
Diversity & Multicultural Issues
Qualitative Research
Systems Tools for Educators
School-Community Relations
Urban Education and Leadership

Special Doctoral Research and Project Interests:

- *Graduate Education and Career Development for Interdisciplinary Scholars and Scientists*
- *Facilitating Interdisciplinary Research and Education*
- *Fostering Virtual Learning Communities*
- *STEM Education and Outreach Program Partnerships*
- *Evaluating Remote Communications and Marketing for an Online Learning Initiative*
- *Online Adult Education: Challenges and Opportunities for Educators*
- *Expanding Educational Opportunities for Children in At-Risk Circumstances*
- *Urban School Success: Promoting Early Learning and Kindergarten Readiness*
- *Academic Leadership & Team Science*
- *Toolbox Facilitated Dialogue Workshop: Pre-Conference 2012 Science of Team Science Conference*
- *Science of Team Science Conference, June 2013 - Abstract Reviewer & Invited Speaker: Graduate Education & Training*
- *Literacy Enrichment for Preschool Children of Teen Mothers*
- *Post MBA/MEd research paper and internship completed with Parkland School District and Muhlenberg College.*
  Special Education-Inclusion Policy and Practice

Lehigh University, Bethlehem, PA

M.B.A. December 1986. M.B.A. Graduate Student Association Representative and Fund-Raising Committee Member

M.ED. Community Counseling, August 1983. Concentration: Higher Education Career Counseling
Master's Internship in Higher Education Counseling and Career Development at Moravian College

DeSales University, Center Valley, PA
B.A. Psychology July 1982. Elective concentration: English
Summa cum laude; completed requirements within 3 years Delta Epsilon Sigma Honor Society Member
Experimental Psychology Department Teaching Assistant
Psychology Department Award for Most Distinguished Academic Performance
Research Project: Social Responsibilities of For-Profit Corporations

COMMUNITY SERVICE AND SPECIAL HONORS

- PA Governor's Appointment: Child Development and Early Learning Council Member
- 2013 Invited Speaker Science of Team Science 4th Annual Conference Panel on Graduate Education and Training,
- Leadership Centre County, Class of 2013
- UPCEA Secretary 2012 and Session Presenter, Mid-Atlantic Regional Conference, *"New Program Discovery & Delivery: Comparison of Face to Face, Blended and Online Learning Environments"*
- 2009 Hosted *Birds of A Feather* Session on Online Learning for Adults at PA Education Technology Expo & Conference
- Invited Participant to Promote Diversity in STEM Education Recruiting & Retention - NSF/IGERT
- National Canal Museum: STEM Education Advisory
- National Organization of Research Development Professionals Member
- Invited Speaker-Women Engineering Professionals Advisory Network (WEPAN): Fostering PBS and University Partnerships for STEM Education-Launch of DESIGN SQUAD (2007)
- Lehigh Valley Child Care-Scholarship Fund: Wrote proposals and solicited numerous grants to fund childcare scholarships for children in at-risk circumstances.

Work Experience:

2010-2013 After federally funded project completed, was awarded a graduate assistantship and also completed administrative work while completing dissertation requirements for completion of the doctorate. Successfully defended February 25, 2013. Degree to be conferred, May 2013.

Professional Experience
PBS 39 WLVT, Bethlehem, PA — March 2008-September 2010
PA e-Learning for Educators Program
PA Project Director

Provided operational, marketing and fiscal leadership for federally funded *Ready-to-Teach* program providing online professional development courses and training for PA educators. Served as the PA liaison for multi-million dollar collaboration between 10 state departments of education and 10 public broadcast organizations. Defined segments and advised Production Department on education grant proposal resulting in $200,000 award for the 2009-2010 PBS 39 production of a series of community education specials on topics including: urban education, students and civic engagement, STEM education, early learning and child development, safe schools, and 21st century learners and teachers.

- Created more selective recruiting, selection and admission process for course facilitators and course developers.
- Implemented assessment and evaluation methods. Incorporated data into continuous improvement planning.
- Within one year of assuming role, exceeded enrollment and retention rates for previous 3.5 years. Streamlined electronic registration and enrollment management process.
- Established partnerships with University and Intermediate Unit collaborators and strengthened relationship with PA Department of Education to enlist support for e-Marketing and content development.
- Completed courses in developing and facilitating online professional development provided by Ed Tech Leaders Online.
- Directed development of ACT 48 courses for PA Educators that specifically addressed needs expressed by PDE and schools for purpose of promoting student achievement, particularly in underserved populations.
- Supervised project assistants and all statewide facilitators and course developers.
- Managed the website development and renewal see www.pennteacher.org

Reason for leaving: When funding ended, completed doctorate at Lehigh University.

PBS Department of Education and Outreach
Director of Education and Outreach

- Provided leadership to the Education and Outreach department and served as member of station leadership team.
- Managed departmental budget and staff. Conducted programs, services, and materials assessment and made operational improvements to existing programs and services.
- Conducted surveys, interviews and meetings with board members, education advisory council, funding and community partners, and area educators to improve services and delivery for diverse public education needs.
- Strengthened all programs primarily those meeting needs of the underprivileged and at-risk community members.
- Created operational templates for all existing programs resulting in reduced costs and greater efficiencies. Hired and supervised graduate intern to provide staff support in critical areas when budget cuts required.
- Created electronic Education and Outreach newsletter.
- Participated in business, non-profit, and local, state and federal government collaborations.
- Provided key support to Production team on all education programming including several grant-funded projects.
- Represented PBS 39 and the local community on the School Study Council, School Emergency Management Council, Community Services for Children and Career Advisory Council Committees.
- Oversaw, helped secure funding and managed budgets and staffing for *Scholastic Scrimmage, Raising Readers, Ready to Learn, Reading is Fundamental, and the PBS Governor's School* programs. *(Accepted PBS/PA Project Director role full-time.)*

LEHIGH UNIVERSITY, Bethlehem, PA August 2003-March 2008
P.C. Rossin College of Engineering and Applied Science
Director of Administration and Special Programs

- Provided administrative and operational support to Dean including personnel and resource management.
- Provided background support for strategic planning and initiative development in collaboration with Chairs Council and Engineering Advisory Board.
- Supervised Dean's exempt and non-exempt operational staff.
- Managed performance appraisal and salary review process for the College.

- Served as liaison between the Dean and RCEAS Department Chairs and Center and Institute Directors and other University staff and faculty.
- Assisted with funding requests for special projects and coordinated outreach programs including the Research Symposia, Charting Horizons and Opportunities for Careers in Engineering and Science (CHOICES) middle school program, and CHOICES summer camps for girls (grades 6-8).
- Coordinated special College sponsored events and projects including the PA Engineering Deans meeting in Harrisburg, RCEAS faculty retreat and the distinguished lecture series.
- Advised activities committee of the Rossin Junior Fellows student leadership organization focused on providing community-building initiatives within the College. (PBS Design Squad-Middle School Program coordinated under this effort.)
- Provided administrative support for special College faculty searches and the University search for the Dean of the College of Business and Economics.
- Received both Dean's and Provost's merit awards for service to College.
- *Reason for leaving: Accepted position with PBS as Director of Education and Outreach.*

Department of Industrial and Systems Engineering
NSF/IGERT Program Coordinator for Global Manufacturing Logistics PhD. Program

- Recruited doctoral students for National Science Foundation endowed integrative graduate education and research training (IGERT) program. Identified highly qualified candidates in coordination with Lehigh faculty and undergraduate academic advisors at partner institutions.
- Handled all admissions inquiries and prospective student issues. Developed marketing strategies to promote the program, increase highest caliber applications and enhance admissions and retention and student success.
- Provided support for enrolled students regarding domestic and international industrial internships.
- Managed student budgets, program accounting, and grant funding documentation.
- Served as liaison between students and other University staff/offices.
- Coordinated distinguished lecturer visits, including inaugural event.
- Invited to participate in special NSF/IGERT initiatives to promote opportunities for under-represented groups relative to STEM education.
  Reason for leaving: Promoted to Dean's Office.

PEPPERDINE UNIVERSITY, Malibu, CA 6/90-6/92
Graduate School of Business
Director of Master of International Business and MBA Career Development
Promoted from Associate Director position within 6 months

- Established and managed comprehensive career development center for new full-time MBA and Master of International Business programs.
- Created and taught professional development course for all first-year students.
- Initiated internship and recruiting programs in U.S., Germany and France.
- Represented students to international prospective employers.
- Provided career support services for students in U.S. and Europe.
- Created all promotional and educational materials and newsletters.
- Established extensive career resource library.
- Supervised three full-time staff and five graduate assistants.
- Co-chaired and managed budget for very successful first annual West Coast MBA Consortium recruiting event.
  (Relocated with family to PA.)

COLUMBIA UNIVERSITY, New York, NY

Graduate School of International and Public Affairs
Assistant Director of Career Development 6/89-6/90

- Managed recruiting and job development program for graduate students.
- Initiated program marketing for international business students.
- Taught credit-based graduate professional development seminar on interest assessment, resume writing, interviewing and job search strategies.
- Supervised support staff and graduate assistants.
- Exceeded year-end recruiting goals by mid-year.
- Selected for leadership training seminar.
- Received special recognition from Associate Dean for supervisory skills.
  (*Accepted promotion with Pepperdine.)*

Lehigh University, Bethlehem, PA
Office of Career Development
Career Counselor 6/88-6/89

- Counseled undergraduate and graduate students and alumni on various career development and employment related issues.
- Assisted with on-campus recruiting and Employer Relations initiatives.
- Created and taught numerous outreach and special topics workshops.
- Administered GREs. Graduate Assistant. 8/82-1/85.

College of Business and Economics 1/86-1/87
Teaching Assistant

- Taught 6 recitation sections for *Organizational Theory and Behavior.*
- Combined case studies, lectures, group exercises.
- Consistently received excellent student evaluations.
- Promoted from course grader.
-

Muhlenberg College, Allentown, PA 10/87-6/88
Student Development Office
Counselor

- Reported to Director of Career Development and Director of Counseling.
- Provided personal and career counseling to undergraduate students.
- Coordinated internship program.
- Conducted workshops.
- Participated in Student Affairs planning group.

Cedar Crest College, Allentown, PA 10/83-10/84
Continuing Education
Adult Education Counselor and Instructor for Special Programs.

- Provided academic and career counseling for adult students.
- Developed workshops and presentations to address specific adult education interests/needs.
- Co-wrote funding proposal and successfully implemented outreach program for economically disadvantaged high school students through the Private Industry Council.

Moravian College, Bethlehem, PA Spring 1983
Counseling and Career Planning Intern

- Administered and reviewed interest inventories. Interviewed and helped select student advisors.

CORPORATE MARKETING EXPERIENCE: 12/86-10/87

Citicorp Retail Services, Inc., Allentown, PA

Marketing Associate

- Assisted in managing private label credit card business.
- Developed client proposals and sales incentive programs.
- Managed credit review staff.
- Conducted staff training in PA, VA and NY.
- Recipient of Citicorp Retail Services Bright Idea Award (1997) for workplace improvement.

IBM Corporation, Bethlehem, PA 3/85-1/87

Marketing and Systems Engineering Assistant

- Conducted customer calls and provided training to existing and prospective corporate clients. Half-time position while enrolled in graduate program.

Committee & Professional Memberships:

- Leadership Centre County: Member Class of 2013
- National Organization of Research Development Professionals (NORDP)
- Community Services for Children-Donley Awards Committee
- Governor's Early Learning Council, Marketing and Communications Sub-Committee
- School Emergency Management Council
- Casa Guadalupe Capital Campaign Committee for Neighborhood Health Center
- PA Shakespeare Festival Circle of Friends
- Career Education Pathways Committee
- LU School Study Council
- Friends of Zoellner Arts

Additional References and Teaching Clearances Available

Valerie C. Holt

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Learning Activities

ROUND 1 SURVEY

Graduate Education to Facilitate Interdisciplinary Research Collaboration

LEHIGH UNIVERSITY

Implied Informed Consent Form for Social Science Research
Lehigh University

Introduction

I hereby agree to participate as a subject in the research project on **"Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Strategies"** conducted by Valerie C. Holt.

It has been explained to me that the purpose of the study is to identify the a) competencies (combinations of knowledge, skills, and attitudes) needed for effective interdisciplinary research collaboration and b) graduate education activities that facilitate the development of the identified competencies.

Procedures

The investigation will employ an iterative Delphi survey methodology.
Phase I. Participants will be provided a list of 17 core competencies previously identified by Gebbie et al.(2008) as being necessary for effective research collaboration. Participants will rate level of agreement with the identified list and will also edit and add to or delete items previously identified. The questionnaire consists of 17 competencies and will take approximately 20 minutes or less.
Phase II. Participants will be asked to identify specific learning activities that facilitate the development of those agreed upon competencies.

Risks/Discomforts and Benefits and Compensation

Risks are minimal for involvement in this study. There are no direct benefits for participants. However, it is hoped that through participation, researchers and practitioners will learn more about competencies needed for effective interdisciplinary research collaboration and graduate student learning activities that facilitate the development of those competencies. There is no compensation for participation.

Confidentiality

All data obtained from participants will be kept confidential and will only be reported in an aggregate format. All questionnaires will be concealed, and no one other than then primary investigator and assistant researcher listed below will have access to them.

Participation

Completion and return of the survey implies that you have read the information in this form and consent to take part in the research. Please print and keep this form for your records or future reference. Your participation is entirely voluntary. You may withdraw at any time, and you may decline to answer specific questions. You have the right to withdraw at anytime or refuse to participate entirely. If you desire to withdraw, please close your internet browser and notify the principal investigator at this email: vah2@lehigh.edu.

Questions about the Research

If you have questions regarding this study, you may contact Valerie C. Holt, at 484-264-8274, vah2@lehigh.edu

Questions about your Rights as Research Participants

If you have questions you do not feel comfortable asking the researcher, you may contact Dr. Jill Sperandio, jiis204@psu.edu or 610-759-3392, or Susan Disidore at Lehigh University's Office of Research and Sponsored Programs at (610) 758-3020 or sus5@lehigh.edu

Please click the **Next** button below to respond to the survey.

Graduate Education to Facilitate Interdisciplinary Research Collaboration

Round 1: Questionnaire

Background:

The purpose of this research study is to identify core competencies required for effective interdisciplinary research collaboration and to identify specific learning activities that facilitate the development of those competencies.

The study results will provide practical guidance to academic leaders and graduate educators engaged in preparing emerging scholars and scientists for a broad range of post-graduate careers that require interdisciplinary research collaboration competence.

Definition of Competency:

According to Parry (1996), competency refers to

> a cluster of related knowledge, skills, and attitudes that affect a major part of one's job (a role or responsibility), that correlates with performance on the job, that can be measured against some accepted standards, and that can be improved via training and development. (p. 50)

The 17 Competencies for Interdisciplinary Researchers:

In an earlier Delphi study, Gebbie et al., (2008) identified 17 observable competencies as necessary for interdisciplinary health research. These 17 competencies will serve as an *initial* framework for discussion though are not intended to be restrictive as the results of this study and the identified learning activities are proposed for a broad range of scholarly careers requiring interdisciplinary research competence.

These previously identified competencies are broadly categorized into three main clusters as follows:

Conduct research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks
2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary rese protocols
3. Investigate hypotheses through interdisciplinary research
4. Draft funding proposals for interdisciplinary research programs in partnership with scholars other disciplines
5. Disseminate interdisciplinary research results both within and outside his or her discipline

Communicate

6. Advocate interdisciplinary research in developing initiatives within a substantive area of stu
7. Express respect for the perspectives of other disciplines
8. Read journals outside his or her discipline
9. Communicate regularly with scholars from multiple disciplines
10. Share research from his or her discipline in language meaningful to an interdisciplinary tea
11. Modify his or her own work or research agenda as a result of interactions with colleagues f fields other than his or her own
12. Present interdisciplinary research at venues representing more than one discipline

Interact with others

13. Engage colleagues from other disciplines to gain their perspectives on research problems
14. Interact in training exercises with scholars from other disciplines
15. Attend scholarly presentations by members of other disciplines
16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks
17. Author publications with scholars from other disciplines

17. Author publications with scholars from other disciplines

Gebbie, K. M., Mason Meier, B., Bakken, S., Carrasquillo, O., Formicola, A., Aboelela, S. W., Glied, S., & Larson, E. (2008). Training for interdisciplinary health research defining the required competencies. *Journal of Allied Health*, 37(2), 65–70.

Round 1 Instructions:

1. For each of the 17 competencies listed, you will be asked to indicate whether you *agree, disagree* or are *neutral* that the identified competency is necessary for effective interdisciplinary research collaboration.
2. You will also be asked to list up to 3 additional individual competencies (knowledge, skills and attitudes) that you consider critical but missing from this initial list.
3. Finally, you will be asked to indicate whether you agree that the three broad categories: *conduct research, communicate, interact with others* capture the main categories of competencies needed to engage in effective interdisciplinary research collaboration?

Note: Aggregated results of this round will be used to draft the final round survey seeking expert opinions about learning activities that facilitate interdisciplinary research collaboration.

Part I.

For each of the 17 competencies listed, please indicate whether you agree, disagree or are neutral that the identified competency is necessary for effective interdisciplinary research collaboration. If necessary, please provide edits.

Conduct research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary research protocols

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

3. Investigate hypotheses through interdisciplinary research

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

4. Draft funding proposals for interdisciplinary research programs in partnership with scholars from other disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

5. Disseminate interdisciplinary research results both within and outside his or her discipline

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

Communicate

6. Advocate interdisciplinary research in developing initiatives within a substantive area of study

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

7. Express respect for the perspectives of other disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

8. Read journals outside his or her discipline

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

9. Communicate regularly with scholars from multiple disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

10. Share research from his or her discipline in language meaningful to an interdisciplinary team

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

11. Modify his or her own work or research agenda as a result of interactions with colleagues from fields other than his or her own

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

12. Present interdisciplinary research at venues representing more than one discipline

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

Interact with others

13. Engage colleagues from other disciplines to gain their perspectives on research problems

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

14. Interact in training exercises with scholars from other disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

15. Attend scholarly presentations by members of other disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

17. Author publications with scholars from other disciplines

◯ Agree ◯ Neutral ◯ Disagree

Suggested edits if needed

Graduate Education to Facilitate Interdisciplinary Research Collaboration

Part II.

The ultimate intent of this study is to identify learning activities that facilitate interdisciplinary competencies.

If you do not think that the 17 competencies adequately capture the necessary competencies for effective interdisciplinary research collaboration, please list up to 3 additional individual competencies (combinations of knowledge, skills, and attitudes).

17 Competencies (Gebbie et al., 2008)

Conduct research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks
2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary rese protocols
3. Investigate hypotheses through interdisciplinary research
4. Draft funding proposals for interdisciplinary research programs in partnership with scholars other disciplines
5. Disseminate interdisciplinary research results both within and outside his or her discipline

Communicate

6. Advocate interdisciplinary research in developing initiatives within a substantive area of stu
7. Express respect for the perspectives of other disciplines
8. Read journals outside his or her discipline
9. Communicate regularly with scholars from multiple disciplines
10. Share research from his or her discipline in language meaningful to an interdisciplinary tea
11. Modify his or her own work or research agenda as a result of interactions with colleagues f fields other than his or her own
12. Present interdisciplinary research at venues representing more than one discipline

Interact with others

13. Engage colleagues from other disciplines to gain their perspectives on research problems
14. Interact in training exercises with scholars from other disciplines
15. Attend scholarly presentations by members of other disciplines
16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks
17. Author publications with scholars from other disciplines

1. Additional Competency 1

2. Additional Competency 2

3. Additional Competency 3

Part III.

The 17 competencies identified by Gebbie et al., (2008) were divided into 3 main categories: *conduct research, communicate*, and *interact with others.*

17 Competencies (Gebbie et al., 2008)

Conduct research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks
2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary rese protocols
3. Investigate hypotheses through interdisciplinary research
4. Draft funding proposals for interdisciplinary research programs in partnership with scholars other disciplines
5. Disseminate interdisciplinary research results both within and outside his or her discipline

Communicate

6. Advocate interdisciplinary research in developing initiatives within a substantive area of stu
7. Express respect for the perspectives of other disciplines
8. Read journals outside his or her discipline
9. Communicate regularly with scholars from multiple disciplines
10. Share research from his or her discipline in language meaningful to an interdisciplinary tea
11. Modify his or her own work or research agenda as a result of interactions with colleagues f fields other than his or her own
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Interact with others

13. Engage colleagues from other disciplines to gain their perspectives on research problems
14. Interact in training exercises with scholars from other disciplines
15. Attend scholarly presentations by members of other disciplines
16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks
17. Author publications with scholars from other disciplines

Please indicate whether you agree that the three broad categories: *conduct research, communicate*, and *interact with others* capture the main competency categories?

◯ Agree ◯ Neutral ◯ Disagree

If you answered Neutral or Disagree, what modifications would you make with regard to the three categories? Please describe.

Part IV.

Are there additional comments you would like to include? (Please describe).

Part V. Demographics

Please take a moment to complete the following questions.

Educational Background

Please enter your field of study in each stage of your education (e.g., physics, electric engineering, etc.)

Undergraduate

Master's

Doctoral

Other

How many years of experience do you have in interdisciplinary research collaboration?

How many years of experience do you have in graduate education and advising?

What is your organizational affiliation?

What is the name of your department?

What is the job title for your current position?

In what country do you live?

Thank you so much for your participation.

Click "Done" to complete.

Valerie C. Holt

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Learning Activities

ROUND 2 SURVEY

[R2] Graduate Education to Facilitate Interdisciplinary Research

LEHIGH UNIVERSITY.

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Strategies

Dear Participants,

Thank you for your thoughtful responses to Round 1 of the study to identify a) competencies (knowledge, skills and attitudes) needed for effective interdisciplinary research collaboration and b) learning activities for graduate students that facilitate the development of those competencies.

The results of the initial survey round yielded the following key observations.

- Broad consensus to eliminate or revise the three distinct categories of competencies (Research/Communicate/Interact) noted as interrelated and resulting in competency redundancies.
  (Link to representative comments)
- Competencies are defined in this study as *observable, measurable and developmental*, however many noted that some of the original items listed could more appropriately be defined as outcomes.
- Competencies that were most frequently suggested to be added to the list related to self-awareness, understanding of one's own discipline within context of interdisciplinary teams, "soft-skills", and team skills.
- Caution that if study's focus is to identify specific learning activities that support the development of individual competencies for effective interdisciplinary research collaboration, then the competencies identified should be stated in terms possible to list associated activities
- Reminder to articulate the distinction between "interdisciplinary education" versus "graduate education to promote interdisciplinary collaboration competence" the later of which recognizes graduate education is still predominately discipline-specific and is the focus of this particular study.

Review Round 2 is organized as follows:

- Feedback from Round 1 with option for final review/edits.
- List of additional competencies proposed by participants. Review requested.

It has been explained to me that the purpose of the study is to identify the a) competencies (combinations of knowledge, skills, and attitudes) needed for effective interdisciplinary research collaboration and b) graduate education activities that facilitate the development of the identified competencies.

Please click the **Next** button below to respond to the survey.

SECTION 1: Feedback for Original List of Competencies

Please note:

- The Delphi methodology adopted in this study allows each participant to reflect on his/her own initial responses as well as the insights offered by the other study participants. This is the final review of suggested competencies.
- Competencies achieving consensus (70% agreement) from the original list and suggested competencies that also receive 70% agreement will be coded and redundant items consolidated to create a final, abbreviated list.

Please review and rate the revised version of the original 17 competencies.

Note: Revised wording of original competencies reflects either exact wording suggested by participant(s) OR reflects suggestions to modify the original competency. You may click on hyperlinks to review participant comments regarding each competency.

[R2] Graduate Education to Facilitate Interdisciplinary Research

1. Use theories and methods of multiple disciplines in developing integrated theoretical and research frameworks

Agreed: 71.4%, Neutral: 9.5%, Disagreed: 19.0% *(Click here to view comments from the panel)*

Recommended Revision:

Work with others to use theories and methods of multiple disciplines to improve understanding of an agreed upon problem or issue.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

2. Integrate concepts and methods from multiple disciplines in designing interdisciplinary research protocols.

Agreed: 81.0%, Neutral: 0.0%, Disagreed: 19.0% **(Click here to view comments from the panel)**

Recommended revision:

Integrate concepts and methods from other disciplines in designing research protocols.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

3. Investigate hypotheses through interdisciplinary research.

Agreed: 57.1%, Neutral: 26.6%, Disagreed: 14.3% **(Click here to view comments from the panel)**

Consensus Not Achieved. Recommend deletion.

◯ Agree (with deletion) ◯ Neutral ◯ Disagree

Comments:

4. Draft funding proposals for interdisciplinary research programs in partnership with scholars from other disciplines.

Agreed: 85.7%, Neutral: 9.5%, Disagreed: 4.8% **(Click here to view comments from the panel)**

Recommended Revision:

Draft research proposals in partnership with scholars from other disciplines.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

[R2] Graduate Education to Facilitate Interdisciplinary Research

5. Disseminate interdisciplinary research results both within and outside his or her discipline.

Agreed: 90.0%, Neutral: 00.0%, Disagreed: 10.0% **(Click here to view comments from the panel)**

Recommended Revision:

Disseminate interdisciplinary research results to various audiences in multiple disciplines

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

6. Advocate interdisciplinary research in developing initiatives within a substantive area of study

Agreed: 61.9%, Neutral: 28.6%, Disagreed: 9.5% **(Click here to view comments from the panel)**

Consensus not achieved, recommend deletion from list.

◯ Agree (with deletion) ◯ Neutral ◯ Disagree

Comments:

7. Express respect for the perspectives of other disciplines. *(Redundancy noted. Edits recommended, some within added competencies list.)*

Agree: 90.5%, Neutral: 4.8%, Disagree: 4.8% **(Click here to view comments from the panel)**

Recommended Revision:

Appreciate and draw value from the perspectives of other disciplines.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

8. Read journals outside his or her discipline.

Agreed: 66.7%, Neutral: 14.3%, Disagreed: 19.0% **(Click here to view comments from the panel)**

Consensus not achieved. "Additional competencies" list addresses concerns expressed (see comments). Suggest deletion as stated.

◯ Agree (with deletion) ◯ Neutral ◯ Disagree

Comments:

[R2] Graduate Education to Facilitate Interdisciplinary Research

9. Communicate regularly with scholars from multiple disciplines. *(Consensus achieved, redundancy noted.)*

Agreed: 100.0%, Neutral: 0.0%, Disagreed: 0.0% **(Click here to view comments from the panel)**

Recommended Revision:

Communicate regularly with scholars from other disciplines.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

10. Share research from his or her discipline in language meaningful to an interdisciplinary team.

Agreed: 100.0%, Neutral: 0.0%, Disagreed: 0.0% **(Click here to view comments from the panel)**

Recommend to accept as stated.

◯ Agree (to accept as stated) ◯ Neutral ◯ Disagree

Comments:

11. Modify his or her own work or research agenda as a result of interactions with colleagues from fields other than his or her own

Agreed: 81.0%, Neutral: 14.3%, Disagreed: 4.8% **(Click here to view comments from the panel)**

Consensus achieved. No edits suggested. Recommend accept as stated.

◯ Agree (to accept as stated) ◯ Neutral ◯ Disagree

Comments:

12. Present interdisciplinary research at venues representing more than one discipline

Agreed: 81.0%, Neutral: 14.3%, Disagreed: 4.8% **(Click here to view comments from the panel)**

Recommended revision:

Present interdisciplinary research at venues outside of one's discipline and at venues representing more than one discipline

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

[R2] Graduate Education to Facilitate Interdisciplinary Research

13. Engage colleagues from other disciplines to gain their perspectives on research problems. *(Consensus, but redundancy especially with Item 9 cited by several. Recommended edits and consolidation for final list.)*

Agreed: 90.5%, Neutral: 4.8%, Disagreed: 4.8% **(Click here to view comments from the panel)**

Recommended revision:

Engage colleagues from other disciplines to gain their perspectives on research problems, themes or topics.

◯ Agree (with edit) ◯ Neutral ◯ Disagree

Comments:

14. Interact in training exercises with scholars from other disciplines.

Agreed: 57.1%, Neutral: 33.3%, Disagreed: 9.5% **(Click here to view comments from the panel)**

Consensus not achieved. "Additional competencies" list addresses concerns expressed (see comments). Suggest deletion as stated.

◯ Agree (with deletion) ◯ Neutral ◯ Disagree

Comments:

15. Attend scholarly presentations by members of other disciplines

Agreed: 80.0%, Neutral: 10.0%, Disagreed: 10.0% **(Click here to view comments from the panel)**

Consensus Achieved. Recommend deletion due to redundancy especially with additional competencies list. (Item cited as outcome/activity versus competency.)

◯ Agree (with deletion) ◯ Neutral ◯ Disagree

Comments:

16. Collaborate respectfully and equitably with scholars from other disciplines to develop interdisciplinary research frameworks

Agreed: 89.5%, Neutral: 5.3%, Disagreed: 5.8% **(Click here to view comments from the panel)**

Suggested Edits (Choose A, B or original):

A. Collaborate respectfully with scholars from other disciplines to develop interdisciplinary research frameworks.

B. Develop interdisciplinary research framework(s) in collaboration with scholars from other disciplines.

◯ A ◯ B ◯ Original

Comments:

17. Author publications with scholars from other disciplines

Agreed: 81.0%, Neutral: 9.5%, Disagreed: 9.5% **(Click here to view comments from the panel)**

Consensus but with qualified comments noting redundancy with Item 5. Recommend deletion due to redundancy and revision of Item 5 wording to include dissemination of research a) presentation and b) publication.

◯ Agree (with deletion rationale if Item 5 is reworded) ◯ Neutral ◯ Disagree

Comments:

For Final Round to Identify Learning Activities could have two options under Disseminate Research a) presentations and b) publications. Thus, could eliminate Item 17 from this list.

◯ Agree (with one item "disseminate" with two parts: present/publish) ◯ Neutral ◯ Disagree

Comments:

SECTION 2: Additional Competencies Recommended by Participants:

Please indicate whether you **agree, disagree or are neutral** that the competency (knowledge, skill, attitude) suggested by a participating scholar is important for effective interdisciplinary research collaboration.

Note: This is the final review round to identify the competencies.

The key for this review is to poll agreement with the importance of the recommendation as a competency. Coding (of items and comments) will then be employed to reduce redundancies and streamline language for the final (abbreviated) list used to identify learning activities.

[R2] Graduate Education to Facilitate Interdisciplinary Research

1. Know individual personal strengths and weaknesses as related to interdisciplinary research.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

2. Be assertive as a learner; asserts one's expertise sparingly.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

3. Demonstrate broad intellectual curiosity to ask questions outside own discipline.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

4. Subject his or her disciplinary discovery to interdisciplinary interpretation and scrutiny.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

5. Know strengths and weaknesses of research approaches of other disciplines.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

[R2] Graduate Education to Facilitate Interdisciplinary Research

6. Teach and learn from collaborators, in self- or group-directed ways. (Includes learning from material artifacts produced by other discipline and informal (non-classroom) style of learning, which requires learning on-the-fly as needed rather than a structured acquisition of basic to more complex concepts.)

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

7. Willingness to engage with others to continually clarify language and the concepts that lie behind language, in constructive dialogue that enhances mutual learning and the construction of shared (or mutually understood) terminology and concepts.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

8. Speak from own disciplinary perspective so that others hear "where you are coming from" in the ways in which your discipline identifies, thematizes, and explores its objects.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

9. Take a meta-disciplinary stance to examine the perspectives of relevant disciplines including his or her own.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

[R2] Graduate Education to Facilitate Interdisciplinary Research

10. Engage in questioning the basic assumptions of all disciplines, including one's own.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

11. Engage in self-critique recognizing the limitations of the interdisciplinary research process and outcomes and envisioning next research steps.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

12. Understand what his/her own discipline can contribute to addressing a problem and how that differs from the contributions of other disciplines.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

13. Maintain an open mind and suspend assumptions of one's own discipline so others can be heard.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

14. Demonstrate critical awareness of the underlying assumptions of own discipline, its scope and contribution and limitations in addressing a given research question.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

15. Learn the languages others use in their work.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

16. Understand how to effectively manage conflict, feedback and credit relative to interdisciplinary team research.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

17. Know how to manage personal conflict while promoting substantive disagreement.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

18. Know how to build trust among collaborators in an interdisciplinary team.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

19. Engage in self-critique and in ongoing iterative review of stages of the research process and products that are generated, being open to revisions as needed.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

[R2] Graduate Education to Facilitate Interdisciplinary Research

20. Frame research questions or problems that are multi-dimensional, relevant, and viable and demand an interdisciplinary approach.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

21. Understand key concepts and principles from participating disciplines of an interdisciplinary team needed to effectively communicate, interact and/or develop protocols and conduct research.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

22. Recognize that other disciplines don't simply bring different perspectives on the research object, but literally bring their own objects to the project and to be able to operate from this understanding of what is going on in the collaboration.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

23. Understand and respect different norms and expectations for responsible conduct of research within different disciplines, including authorship and protection of human subjects.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

24. Work collaboratively with equal power sharing and mutual learning of others' languages, modes of working, and epistemic worldviews.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

25. Able to hear in the things one's collaborators say "where they are coming from" in terms of how their discipline identifies, thematizes, and explores its objects

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

26. Contribute to the creation of collective intelligence that includes: thinking with team, adapting individual contributions, trusting value of other contributors, and negotiating differences.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

27. Demonstrate familiarity with (the literature of) pertinent interdisciplinary fields and approaches.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

28. Have knowledge of the strengths and weaknesses of the experimental approaches of other disciplines.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

29. Develop team skills in order to strengthen team structure and dynamics.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

30. Contribute effectively to the work of the team, e.g. being a team player, recognizing where one's work fits, having expertise to draw on most relevant aspects of own discipline for the problem at hand.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

31. Know how to develop a shared interdisciplinary vision with collaborators, communicate it effectively, and revisit it at regular intervals to determine if changes are required.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

32. Understand how to effectively deal with conflict and credit when working in interdisciplinary team.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

33. Use group methods of brainstorming that get people out of their disciplinary boxes.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

34. Build skills for team facilitation and leadership.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

35. Reflect as a group on collaborative interactions and outcomes

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

36. Engage in dialogue, negotiation, and iterative learning processes to craft common ground and leverage synergies across disciplines/perspectives.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

37. Demonstrate familiarity with research products and key literature (e.g. journal articles, blog posts, data sets) of pertinent interdisciplinary fields and approaches.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

38. Effectively interact with and contribute to varied educational opportunities with scholars from other disciplines, e.g. seminars, conferences, scholarly presentations, and research symposia.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

[R2] Graduate Education to Facilitate Interdisciplinary Research

39. Define experimental questions or identify problems that cannot be solved through a single disciplinary approach.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

40. Integrate insights from multiple disciplines.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

41. Develop feasible approaches to addressing the research hypothesis and conversely to abandon approaches that are not feasible. (A feasible approach is one in which time, talent and funding all appear sufficient to make a contribution to the creation of knowledge.)

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

42. Engage in ongoing iterative review of stages of the research process and products that are generated, being open to revision as needed.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

43. Question the very idea of 'integration' as necessary for interdisciplinary communication and collaboration: what is integration and will it help achieve research goals?

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

44. Understand strategies for interdisciplinary team communication including clarifying the meanings of key concepts and appreciating the perspectives of other disciplines.

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

45. Understand strategies for performing interdisciplinary research

◯ Agree ◯ Neutral ◯ Disagree

Edit/Comment

Are there additional comments you would like to include? (Please describe.)

Thank you so much for your participation.

Click "Done" to complete.

Valerie C. Holt

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Learning Activities

ROUND 3 SURVEY

[R3] Graduate Education to Facilitate Interdisciplinary Research

LEHIGH UNIVERSITY.

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Strategies

Dear Participants:

Thank you for your thoughtful participation in the study to identify the a) competencies needed for effective interdisciplinary research collaboration (IDRC) and b) graduate-level learning activities that facilitate the development of those competencies. Each of you has made an important contribution to this effort to provide practical support for emerging scholars and scientists.

Below is the link to Round 3 of the study. This round involves the critical task of identifying specific activities that help graduate students develop the competencies agreed to be important for effective IDRC.

Please submit your responses by **Friday, December 21, 2012.**

The data collection phase of the study will then conclude with one *final review/comment* round after all learning activities are compiled and coded. All participants will receive a final report of the results of this study.

I am grateful for the generous time and commitment each participant has offered to this endeavor and hope that you will continue through this next round. If you have any questions, or concerns, please let me know.

Respectfully,
Valerie.

Please click the **Next** button below to respond to the survey.

Part 1: Validation of Aggregated List of Critical Competencies.

The aggregated list of competencies used to identify learning activities includes those items that 75% or more participants agreed are most important for effective interdisciplinary research collaboration.

Please review the aggregated list of competencies (*Click Here*) and answer the following question before proceeding to Part II.

Do you consider the aggregated list of competencies, agreed by at least 75% of the participants in this study to be important for effective interdisciplinary research collaboration, acceptable for the purposes of further identifying learning activities that facilitate the development of those competencies?

◯ Yes ◯ No

Comment(optional)

(**Note:** Coding was employed to create a final list of competencies to be used to identify learning activities. Please **click here** for more detail about the process employed to finalize the final list.)

[R3] Graduate Education to Facilitate Interdisciplinary Research

Part II: Identification of Learning Activities that Facilitate the Development of Important Competencies for Effective Interdisciplinary Research Collaboration.

For each competency, please list up to 3 **learning activities** at the graduate student level, that you consider helpful for facilitating the development of that specific competency. Please try to be as direct and concise as possible in linking the suggested activity with the competency.

For the purpose of this study **learning activities** may be **broadly defined** and *may range from highly formal and structured activities, to more informal and non-structured activities.* The idea is to generate suggestions and options for graduate student mentors and academic leaders who may be from very different institutions and are considering a host of options that support graduate education in this area.

Definition of Competency:
According to Parry (1996), competency refers to

> a cluster of related knowledge, skills, and attitudes that affect a major part of one's job (a role or responsibility), that correlates with performance on the job, that can be measured against some accepted standards, and that can be improved via training and development. (p. 50)

1. Demonstrate broad intellectual curiosity to ask questions across disciplines.

Learning Activity 1

Learning Activity 2

Learning Activity 3

2. Recognize personal strengths and weaknesses as related to interdisciplinary research collaboration.

Learning Activity 1

Learning Activity 2

Learning Activity 3

3. Demonstrate critical awareness of the underlying assumptions of own discipline, its scope and contribution and limitations in addressing a given research question.

Learning Activity 1

Learning Activity 2

Learning Activity 3

[R3] Graduate Education to Facilitate Interdisciplinary Research

4. Engage colleagues from other disciplines to gain their perspectives on research problems, themes or topics.

Learning Activity 1

Learning Activity 2

Learning Activity 3

5. Share research from own area of expertise in language meaningful to an interdisciplinary team.

Learning Activity 1

Learning Activity 2

Learning Activity 3

6. Collaborate with others to integrate theories, methods and insights of multiple disciplines to improve understanding of problem or issue.

Learning Activity 1

Learning Activity 2

Learning Activity 3

7. Subject own disciplinary discovery to interpretation and scrutiny by researchers from other disciplines.

Learning Activity 1

Learning Activity 2

Learning Activity 3

8. Evaluate the assumptions and limitations of all disciplines in interdisciplinary collaborative initiatives.

Learning Activity 1

Learning Activity 2

Learning Activity 3

9. Maintain an open mind in order to clearly hear perspectives of others during explorative interdisciplinary dialogues.

Learning Activity 1

Learning Activity 2

Learning Activity 3

10. Understand how own expertise can contribute to addressing a problem and how that differs from the contributions of others in interdisciplinary collaborations.

Learning Activity 1

Learning Activity 2

Learning Activity 3

11. Modify own work or research agenda as a result of interactions with colleagues from fields other than own.

Learning Activity 1

Learning Activity 2

Learning Activity 3

12. Integrate concepts and methods from multiple disciplines in designing research protocols.

Learning Activity 1

Learning Activity 2

Learning Activity 3

13. Develop interdisciplinary research framework(s) in collaboration with scholars from other disciplines.

Learning Activity 1

Learning Activity 2

Learning Activity 3

14. Build trust among collaborators in an interdisciplinary team.

Learning Activity 1

Learning Activity 2

Learning Activity 3

15. Understand strategies for interdisciplinary team work and communication including clarifying the meanings of key concepts and appreciating the perspectives of other disciplines.

Learning Activity 1

Learning Activity 2

Learning Activity 3

16. Develop team skills in order to strengthen team structure and dynamics.

Learning Activity 1

Learning Activity 2

Learning Activity 3

17. Build skills for team facilitation and leadership.

Learning Activity 1

Learning Activity 2

Learning Activity 3

18. Understand and effectively manage conflict, feedback and credit relative to interdisciplinary team research.

Learning Activity 1

Learning Activity 2

Learning Activity 3

[R3] Graduate Education to Facilitate Interdisciplinary Research

24. Draft research proposals and author publications in partnership with scholars from other disciplines.

Learning Activity 1

Learning Activity 2

Learning Activity 3

Are there additional comments you would like to include? (Please describe.)

Thank you so much for your participation.

Click "Done" to complete.

Valerie C. Holt

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Learning Activities

ROUND 4 SURVEY

[R4] Graduate Education to Facilitate Interdisciplinary Research

LEHIGH UNIVERSITY

Graduate Education to Facilitate Interdisciplinary Research Collaboration: Identifying Individual Competencies and Developmental Strategies

Dear Panelists:

This is the final review round of the study to identify a) competencies needed for effective interdisciplinary research collaboration and b) graduate level learning activities that facilitate the development of those competencies.

These 3 review questions should take only 5 minutes.
Please respond by Friday, January 20, 2013.

1. The activities suggested in Round 3 have been coded and have yielded clear patterns relative to the categories of learning activities. After reviewing the activities clusters (*Click Here*) and the activity cluster-competency grid (*Click Here*), please briefly answer the following.

a. Are these categories generally agreeable to you?

- ◯ Yes
- ◯ Neutral
- ◯ No

b. Are there missing categories that you expected to see or would like to include? Please describe.

2. Are there any additional examples, suggestions, links, resources, or considerations you would like to offer relative to guiding academic leaders and graduate student mentors trying to understand the competencies and learning activities associated with interdisciplinary research collaboration?
Please describe.

3. All individual responses in this study will be held in confidence, however will you allow your name and one paragraph biography to be listed along with the other study participants as an appendix in the dissertation document?

- ◯ Yes
- ◯ No

The success of any Delphi consensus study rests in the quality of the participants involved and I could not have asked for a finer group of scholars. I am grateful for the thoughtful comments and suggestions you have shared. The project results reflect the group member's deep knowledge and commitment for encouraging the professional development of the next generation of scholars and scientists and I look forward to sharing the detailed final report of this study with each of you after February 25, 2013.

With much appreciation and respect,

Valerie.