THE DEVELOPMENT OF RESEARCH NETWORKS AMONG EARLY-CAREER FACULTY MEMBERS IN THE SCIENCE, ENGINEERING AND HEALTH DISCIPLINES

By

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ABSTRACT

The purpose of this study was to develop a better understanding of the patterns and processes of collaboration in the performance of research, as well as to understand why and how early-career faculty members engage in collaborative partnerships. With an eye toward institutional policy and academic programming, special emphasis was placed on how faculty members perceive the role of their diverse developmental experiences as they relate to the acquisition of collaboration skills. Data from the National Science Foundation's Survey of Doctorate Recipients were used, as well as individual interview data with early-career faculty members from a single public research university.

The results of this study provide strong support for the use of social network theory's strength of weak ties hypothesis in developing our understanding of how collaborative processes work and are elaborated upon. Developing this understanding is increasingly critical as our knowledge base deepens, our research communities expand and become more diverse, and our research questions become more complex. Collegial networks, both physical and virtual were found to be the key to bringing in information from pertinent knowledge hubs and applying it in innovative ways to the questions that attract our imagination.

The findings of this study also have significant implications for practice. Faculty members were found to have had diverse collaborative experiences throughout their undergraduate, graduate, postdoctoral, and faculty careers and these experiences had profound effects in terms of orientating faculty members toward collaborative research and developing the necessary skills to work with colleagues both near and far. Institutions of higher education could do a great deal to facilitate collaboration on their campuses and with scholars beyond the campus walls by training tomorrow's faculty members in how to engage others in research production,

providing faculty members with opportunities on campus to learn about each other's work, and by supporting faculty participation in professional conferences. Granting agencies, on the other hand, were found to have enormous power in terms of facilitating and inhibiting collaborative research. By providing the funding that enables collaborative research to take place, agencies were found to be critical partners. In order to maximize their effectiveness, however, programs, policies, practices, and lines of communication need to be improved to foster and further enable innovative collaborations. Risk aversion, short grant periods, and rigid reporting requirements were found to inhibit collaboration and made adaptation to unanticipated developments in research very difficult. The study concludes that there is great potential for increasingly synergistic and complementary programs between institutions of higher education and granting agencies supporting collaborative research.

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TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

"Accelerating global flows of people and information have formed new communities and networks across social and political borders. Higher education is one such globalised knowledge community in which new patterns of knowledge, accreditation, research alliances, and social and professional relationships are emerging" (Luke, 2005, p. 159).

Context of the Study

Overview

The purpose of this study is to examine when, why, how, and to what perceived effect early-career faculty members develop and utilize the different collaborative networks, especially global, that they need to succeed in their research careers. Given the increasing prevalence of both researchers with international status in the United States (Lee, 2001; National Science Board [NSB], 2003; NSB, 2008; Tremblay, 2005) and postdoctoral research appointments among doctoral recipients in the science, engineering, and health (SEH) disciplines (Hoffer, Grigorian, & Hedberg, 2008; Regets, 1998; Regets, 2002), emphasis will be placed in this study on the potential role the postdoctoral experience plays in the development of collaboration skills and how collaboration differs between U.S. citizens and non-citizens.

Improvements in information technologies, immigration regulations that favor mobility of the highly skilled, federal and institutional policies designed to encourage collaborative research, and the growing complexity of research problems and protocols have brought about significant changes in how and with whom research is conducted and knowledge produced (Adams & Clemmons, 2009; Cornelius & Espenshade, 2001; Etzkowitz, Webster, & Healey, 1998; Freeman & Hill, 2006; Katz & Martin, 1997; Levin, 1992; Luke, 2005; National Science Board [NSB], 2010; Ribes & Bowker, 2011; Szelényi, 2003; Tremblay, 2005). In particular, Marginson (2009) observes that, "The production and dissemination of knowledge goods

converges with the extension of communications and expansion of markets" (p. 42). Today's researchers, especially in the SEH disciplines, must be increasingly collaborative if they are to remain fully informed in their fields, continue to compete effectively for funding and recognition, as well as maintain innovative and productive research programs at an international level (Adams & Clemmons, 2009; Etzkowitz, Webster, & Healey, 1998; Jones, 2010[a]; Jones, Wuchty & Uzzi, 2008; Katz & Martin, 1997; Koschmann, Lewis, & Isbell, 2011; Lawani, 1986; Levin, 1992; Luke, 2005; National Science Foundation, 2011; Regets, 2007; Stephan & Levin, 1992). Underscoring this point, Stephan and Levin (1992) note that, "Good science necessitates knowledge of the frontier… Good science also requires up-to-date equipment and access to other scientists knowledgeable about what is going on in the field. Rarely does good science occur in isolation" (p. 4).

If collaboration is understood as essential in today's research environment (Kezar & Lester, 2009; Howard, 2011), a case that will be made in the pages that follow, it is important to understand who is collaborating with whom, how those collaboration skills are obtained and operationalized, and how those collaborations affect the research conduct (Eddy, 2010; Kezar & Lester, 2009). These are the fundamental questions that this study seeks to address. There is also a larger overarching purpose to this study, however, which is to develop insights into the patterns and processes of, as well as the motivations behind collaboration in the performance of research. By comparing existing quantitative and original qualitative data, an expanded understanding of collaboration processes and their complexities is developed. This informs our understanding of the limits of existing data, while guiding future research focusing on collaborative research processes.

Increased Scholarly Competition and the Expansion of Knowledge Necessitate Collaboration

As doctoral recipients enter into increasingly competitive academic careers, they are expected to be productive. Collaboration, defined for the purposes of this study as working with other scholars in the performance of research, is seen as increasingly important as these scholars seek to make original contributions to their fields, as well as gain public recognition and support for their research (Balog, 1979/80; Beaver & Rosen, 1978; Beaver & Rosen, 1979[a]; Beaver & Rosen, 1979[b]; Eddy, 2010; Hodder, 1979/80; Howard, 2011; Jones, 2010[a]; Jones, Wuchty, & Uzzi, 2008; Katz & Martin, 1997; Kezar & Lester, 2009; Koschmann, Lewis, & Isbell, 2011; Lawani, 1986; National Science Foundation, 2011; Pao, 1980; Pao, 1981; Pravdic & Oluic-Vukovic, 1986; Price, 1963; Price, 1986; Price & Beaver, 1966). Evidence of the increase in research competition is reflected, in part, by growing worldwide expenditures on SEH research. Such expenditures increased at a rate of 7% per year overall in the ten years between 1996 and 2007 (NSB, 2010). Furthermore, that increase reflects a dramatic internationalization of the research effort, with the proportion of expenditures by countries outside North America and Europe, particularly those in Asia, growing at a much faster rate (NSB, 2010).

Just as research expenditures have grown, so too have publication rates. The overall growth rate for academic publications from 1960 to 2010 averaged 5.5% per year, resulting in a doubling of the publication rate every 13 years (Jones, 2010 [a]). In 2006, 941,000 scholarly articles were published, 846,900 (90%) of which were in the science and engineering fields (Jones, 2010 [a]).

As the volume of knowledge production has increased, the 'burden of knowledge' on the individual researcher has also increased just as a scholar's capacity to know the research in his or her field decreases (Jones, 2009; Jones, 2010 [a]; Howard, 2011).

Referencing the 5.5% annual growth rate in publications, Jones (2010[a]) writes, "If any particular individual meaningfully engages only a fixed number of such articles, then the fraction of extant knowledge known by an individual would decline at the same rate: -5.5% per year" (p. 2). This points to contributing factors that lead to longer doctoral programs, the narrowing of expertise over time, and an increase in the prevalence of postdoctoral training positions in preparation for academic careers (Jones, 2009). It also illuminates a context for collaboration with other researchers who can bring their unique knowledge to bear on a research problem and potentially enhance the primary researcher's unique contributions to the field and chances for publication.

Just as scholarly publication numbers have increased generally and in the science and engineering disciplines in particular, coauthored scholarly articles in the science and engineering fields grew from 40% in 1988 to 64% by 2008 (NSB, 2010). Researchers are also increasingly coauthoring articles with scholars from other institutions in the same country (42% in 2008, up from 32% in 1988), and coauthoring articles with collaborators from more than one country (22% in 2008, up from only 8% two decades before) [NSB, 2010]. In the context of increasing world-wide expenditures on research and development in the past ten years or so (NSB, 2010), this last finding on international co-authorship is understandable, but also interesting as it implies that as expenditures on research increase across areas of the world, so too do the connections between the researchers located in those areas and colleagues in other parts of the world. This has led many to believe in a growing "death of distance" in the area of knowledge production, by

which they mean that physical location becomes increasingly irrelevant with advances in technology, communications, and transportation (Jones, Wuchty & Uzzi, 2008, p. 1259).

While the death of distance premise may, at least in part, be true, the conditions under and mechanisms by which scholars become connected with their colleagues from afar have not been clearly elucidated in the literature on collaboration. In fact, some have found that contrary to those proclaiming a death of distance between researchers, selectivity has actually increased in recent years with elite institutions and their researchers gaining privileged access to cutting-edge knowledge and technologies at higher rates than ever before (Jones, Wuchty, & Uzzi, 2008). This will be discussed in more detail in the pages that follow.

Citation data also speak to the growing network of scholarly research, and possibly to the growing interconnectedness of researchers themselves. Within the 941,000 articles published in 2006, 4,372,000 unique journal articles were cited by their authors (Jones, 2010[a]). Placed within a growth context, the publication *Science and Engineering Indicators 2010* indicates that between 1992 and 2007 citations in U.S. science and engineering articles of publications from other countries increased significantly (from 6% overall in 1992 to nearly 10% in 2007) [National Science Board, 2010]. Furthermore, while U.S. researchers have been increasingly citing articles from scholars publishing in China, India, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand, international citation data within European Union publications have seen the most dramatic increases, rising from 17% in 1992 to over 23% in 2007.

This evidence suggests that scholars are bringing more and more of the work of others into their research. As the rate of growth in publications continues to grow exponentially and investment of research dollars continues to expand world-wide, the ability of an individual

researcher to keep pace with new research in a meaningful way and incorporate others' findings into his or her scholarship at a proportional level will decline over time (Jones, 2010[a]). Research partnerships and the citing of the work of others who are also engaged in their own research partnerships are natural solutions to the growing burden of knowledge and enable a deeper exploration of the literature within the fixed period that scholars have prior to timely publication of their work.

The Global Knowledge Economy

The overarching context for this increasing level of collaborative activity in academic production is a growing global knowledge economy in which knowledge-intensive innovation has become central to industry and economic competitiveness (Marginson, 2009; NSB, 2010; Ribes & Bowker, 2011), and access to knowledge has become a central concern (NSB, 2010; Renault, Cope, Dix, & Hersey, 2008). Universities are at the center of this knowledge economy, as producers and consumers of open source knowledge, defined as "free knowledge goods" that are produced, exchanged and generally available to the public (Marginson, 2009, p. 41); producers and consumers of knowledge-intensive products in the form of intellectual property and commercial know-how sold in the marketplace; and as producers and consumers of knowledge goods that have both public- and private-good characteristics (Adams & Clemmons, 2009; Luke, 2005; Marginson, 2009; NSB, 2010; Renault, Cope, Dix & Hersey, 2008).

Across all forms of knowledge production, however, empirical evidence suggests that academic researchers are increasingly collaborative with partners beyond their institutions' walls (Adams, Chiang, & Starkey, 2001; Adams & Clemmons, 2009; Boardman & Corley, 2008; NSB, 2010). Adding to the coauthorship data cited previously, a study of 4.2 million scholarly

works published over three decades found that multi-university collaborations are both the fastest growing kind of authorship structure and create the foundation for the production of papers with the highest impact factors, as measured by how frequently a particular article is subsequently cited in the literature (Jones, Wuchty, & Uzzi, 2008). Jones, Wuchty, and Uzzi (2008) also established that multi-university collaborations rose across all disciplines, but that those rises were the most dramatic within the sciences and engineering, as well as the social science disciplines. What we do not have a firm understanding of, however, are how different factors affect researchers' underlying motivations to collaborate. Nor do we understand the mechanisms colleagues employ to find inter-institutional collaborators on the one hand, and engage them in collaborative research on the other.

The Collaboration Problem: Producing Innovative Research within a Complex and Highly Interpersonal Global Knowledge Economy

The distinctions between forms of knowledge production are increasingly blurred within the higher education context (Luke, 2005; Marginson, 2009). Luke (2005) observes, "Once knowledge and education become commercialized, they are transformed into a purchasable private good – no longer a public good accessible to all regardless of geography or socioeconomic circumstances. The implications for the future of public education and public archives of knowledge such as university libraries and scholarly publishing are dire. Arguably, the 'user pays' rationale has already changed the rules for the dissemination of and access to knowledge generated by academic research, which is fast fading as a public good for public access and benefit" (p. 165).

Nevertheless, references to both open source and commercial knowledge imply that the knowledge economy cannot be wholly explained through traditional economic descriptors.

Rather, knowledge flows, defined by Marginson (2009) as the global cache of knowledge that enters the common worldwide knowledge system and is subject to monetary and non-monetary exchange, are driven by human beings and their negotiations with one another. Thus, the flow of knowledge, both commercial and open source, is not an entirely market-based phenomenon, but also inherently social and, as that flow becomes more global, culturally complex (Katz & Martin, 1997; Marginson, 2009; Walton & Guarisco, 2007).

Emphasizing the interpersonal nature of knowledge flows, Walton and Guarisco (2007) explain that, "knowledge is socially constructed, based on experience and transferred by ongoing participation and negotiation within an interactive social network" (p. 360). As the knowledge economy grows and becomes more global and complex, and as those involved in driving knowledge flows become more diverse, person-to-person collaboration and general awareness of the rapidly expanding volume of scholarship from other researchers becomes all the more essential (Kim, Lee, & Marschke, 2009). Evidence of increasing levels of coauthorship, greater collaboration between universities, the higher impact of articles emerging from collaborative scholarship, and the increasingly complex web of citations in scholarly works all point to the social nature of research today.

Ironically, however, with the increasing complexity of the research environment and diversity of the researchers themselves comes the challenge of keeping knowledge flows active. Swan (1999) writes, "Whilst it might be relatively easy to share knowledge across a group that is homogenous, it is extremely difficult to share knowledge where the group is heterogeneous" (p. 11). Walton and Guarisco (2007) also emphasize the challenges of sharing knowledge within an increasingly heterogeneous community of scholars, pointing out that as the exchange of

information increasingly transcends boundaries, the challenges of geographic distance, language, and culture become more pervasive.

A significant factor that contributes further to these challenges is the fact that knowledge does not move smoothly to and from all corners of the world as collaboration occurs, but becomes structured and imbued with new social meanings as it passes through our institutions and publication systems (Marginson, 2009). As such, the individual researcher's human capital (a person's knowledge, skills, as well as cultural and social experiences that increase a person's ability to do their work well and produce at a higher rate [Psacharopoulos, 2006]), becomes an integral part of the highly personal and subjective process of receiving, interpreting, integrating, expanding upon, and conveying new knowledge. If knowledge itself is imbued with social meaning, the social individual will also bring his or her own knowledge, experiences, assumptions, and meanings into the process of acquiring, interpreting, and using new knowledge from the social networks he or she is connected to. The researcher, therefore, must choose the features of new knowledge that are most important, develop an understanding of how those features comport with his or her existing knowledge and understanding of the phenomena at hand, and integrate that new information into his or her work in a fundamentally personal way.

In this sense it is important to understand how researchers' credentials, training, cultural background, and/or knowledge networks might impact the way that they go about the process of new knowledge acquisition and application. Individuals' preferences toward different forms of collaboration, their motivations for collaboration, their propensity for acquiring collaboration skills, and the way that they make use of collaborative partnerships may be affected to varying degrees by these factors. It is for these reasons that this study examines the role of both the

postdoctoral research training experience, as well as country of origin on faculty members' collaborative research practices.

It is important to note that within the knowledge economy, the channeling and restricting of knowledge can create inequities in which researchers in certain locations do not have access to the knowledge, either open source or commercial, that can propel their research forward (Jones, Wuchty, & Uzzi, 2008; Kenway & Fahey, 2006; Mc Auliffe & MacLachlan, 2005). Luke (2005) asserts that just as new technologies provide us with access to the world, they also create a "digital divide" in which those who have access to hardware and information become ever-more separated from their colleagues who do not have such access (pp. 168-169). In this sense, our knowledge economy remains more bounded by place than truly global in that a scholar's physical location and local access to world-wide knowledge resources still has an enormous impact on his or her ability to conduct informed, cutting-edge research (Altbach, 2002; Ellerman, 2006; Jones, Wuchty, & Uzzi, 2008; Kapur and McHale, 2005; Kenway & Fahey, 2006; Mc Auliffe & MacLachlan, 2005; Solimano, 2002; Welch & Zhen, 2008).

Research Questions

Given recognized restrictions to knowledge flows and Walton and Guarisco's (2007) assertion that, "we create knowledge goods in and via our communicative associations" (p. 45), it is incumbent upon us to understand when and why communicative associations are developed; how they are operationalized; how different forms of collaboration uniquely contribute to the discovery process, and who is successfully engaging in these communicative associations to overcome the knowledge access barriers they face in research production.

To further develop our understanding of these issues, this research integrates both quantitative and qualitative methods of inquiry. The study uses both national data from the National Science Foundation and original qualitative data from interviews to gain a better understanding of the forms of collaboration that are most common among early-career faculty members, as well as the factors that predict such collaborative activity. The answers to this line of inquiry regarding collaboration patterns were used, along with social network theory's weak ties hypothesis, to define the parameters for the qualitative interviews' exploration into the motivations behind and mechanisms for collaboration, as well as how researchers related their training to their development as collaborative researchers.

Quantitative Research Questions. For the preliminary quantitative stage of this study, two questions served to guide the analyses. These questions were:

- *What forms of collaborative research activity are most representative of early-career faculty researchers working in the U.S.?*
- *What factors predict early-career faculty researchers' participation in collaborative activities, with particular attention to the unique effects of field of study, institutional type, postdoctoral research experience, and/or international faculty status?*

In this stage of the study, data from the 2006 Survey of Doctorate Recipients (SDR) were used to evaluate which forms of collaborative research activity were most representative of early-career faculty members working in the United States. Collaborative research activity is defined by the 2006 SDR in terms of working with an immediate group or team, working with others in the same organization, working with individuals in other organizations in the U.S., and working with individuals located in other countries.

For the first quantitative research question, the population of early-career faculty members under study were isolated and frequency analyses were run based on the four forms of collaborative research activity highlighted on the 2006 SDR. For the second quantitative research question, as the collaboration measures that served as the dependent variables were all dichotomous, binomial logistic regression was used to determine the degree to which respondents' field of study, institutional type, international status, age, years since earning the doctorate, tenure status, gender, and/or postdoctoral experience predicted the four collaborative activity types articulated above. The rationale for including these independent variables is discussed in Chapter 3. Fields of study were categorized into four groups for the purposes of analysis. These included the life sciences, the physical sciences, the social sciences and engineering.

Qualitative Research Questions. The final stage of the study employs qualitative methods. While the collaboration data from the 2006 SDR are useful as a guide in this research, they are limited with respect to addressing the overarching purpose of this study. The 2006 SDR does not, for example, allow for an examination of the possible relationship between a person's postdoctoral training experience or field of study and the development of collaboration skills. It does not enable an examination of the relative impact of faculty members' doctoral program advisors, postdoctoral mentors, or faculty colleagues. Nor does it allow for a deeper exploration of how faculty members with an international status or particular gender might differ on their understanding of and perceptions related to collaboration as compared to their U.S. status peers.

Using the findings of the quantitative study as a guide, in-person semi-structured interviews were conducted with SEH faculty members at a single research institution who shared

the characteristics of the population studied on the 2006 SDR. Four thematic questions served to guide the interviews. These were:

- *What forms of collaboration are participants engaged in with regard to their research activities?*
- *What are the mechanisms early-career faculty members employ in the development of their collaborative research networks, how are these networks maintained, and why are collaborations pursued?*
- *What is the perceived relationship between the collaborative work done in graduate school, the postdoctoral research period (if applicable), and the respondents' faculty careers?*
- *Do faculty members with international status and domestic status differ in how they perceive the constraints on and opportunities available to them as they relate to the development of collaborative partnerships?*

Details regarding the selection of informants, human subjects protections, construction of the semi-structured interviews, data transcription process, coding, and the process of data analysis are discussed in Chapter 3.

Theoretical Overview

Early-career faculty members were selected as the focus population of this study for a variety of reasons. In a relatively short period of time, SEH researchers go from the structured and supervised doctoral student experience to an environment in which they are expected to independently generate original research and form the collaborative partnerships they need to succeed in the global knowledge economy. The record of research accomplishment during this

time has been shown to be one of the primary factors considered in the tenure and promotion process (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). Given the pressure to produce and publish innovative research, the higher impact of and citation number for articles published by authors of more than one institution (Adams & Clemmons, 2009; Adams, Gurney, & Marshall, 2007; Jones, Wuchty, & Uzzi, 2008), along with the increasing burden of knowledge upon the individual researcher and the growing complexity of the research problems themselves (Adams & Clemmons, 2009; Jones, 2009; Jones, 2010a), collaboration understandably takes center stage during this period.

Social network theory in general and its strength of weak ties hypothesis in particular were used to frame the study and contextualize the results. While social network theory is described in detail in Chapter 2, for the purposes of this introduction this theory explains how individuals develop and utilize their personal connections or ties to exchange and produce knowledge. Social network theory prioritizes the complex interpersonal relationships people establish in the performance of their work and, in this study, how these relationships affect the processes and outcomes of research. Within this theory the strength of weak ties hypothesis has been used to explore and explain the development of collaborative research networks of faculty members. Simply stated, the strength of weak ties concept hypothesizes that the more an individual is connected to people in different knowledge communities or hubs, the more likely they are to learn new information beyond their immediate sphere of regular intellectual activity (Eddy, 2010). This is important in the context of this study as it explains both the value of developing more extended research networks within and across disciplines, as well as the possible motivations behind participation in certain networking activities as faculty members seek out new and work to enhance their existing collaborations.

The Need for a Study on Collaborative Research Processes

Collaboration as a topic for research is not new and in fact has become an area of enormous popular and scholarly interest in recent years as people come to understand its essential role in the production of new knowledge. As a case in point, in December of 2011, the National Science Foundation released the *Mosaic Report* in which it articulated key directions for future research for its Directorate of Social, Behavioral, and Economic Sciences. In this report they cite a series of white papers that had been submitted to NSF that focus on the importance of developing a stronger understanding of collaboration within the research enterprise. In particular, the report asserts that the future of scientific research is fundamentally data-intensive, interdisciplinary, and collaborative.

Reading the white papers themselves, Ribes and Bowker (2011) write, "Today, knowledge production and sharing are being transformed by sweeping changes in information technology, market relations, and patterns of collaboration" (p. 1). In a separate white paper, Koschmann, Lewis, and Isbell (2011) make the case as well, stating, "The ability of individuals, groups, and organizations to make meaningful and productive decisions together will be a hallmark of the twenty-first century. Collaboration needs to play a prominent role in all aspects of society. As such, the full force of the social and behavioral sciences is needed to expand our understanding of collaboration and how we can make better decisions collectively" (p. 2).

Kezar and Lester (2009) situate this need to develop a fuller understanding of collaboration within the context of a higher education institutions themselves, emphasizing that the creation of a collaborative campus environment conducive to research production will not happen by accident. Rather, they emphasize, it will be a process that is both intentional and deliberate. Eddy (2010) concurs, writing, "Central to organizational or individual collaborations

are a series of processes. Better understanding of the components of how collaborations develop can thus result in more effective joint ventures" (p. vii).

While there is indeed a substantial body of literature on knowledge flows, this literature focuses primarily on the products of collaboration, rather than on the development of collaboration skills themselves, the patterns of collaboration, the mechanisms researchers employ when accessing and contributing to the knowledge economy, or on how researchers effectively apply their collaborative efforts to their research (Eddy, 2010; Katz & Martin, 1997; NSB, 2010; Renault, Cope, Dix, & Hersey, 2008). Measures of the benefits and outcomes of collaboration, such as the level of technology transfer, the number of new licenses, the creation of new industries and jobs, the number of citations and patents, coauthorship rates, and the degree to which new products are created, are indeed critically important to researchers and their institutions. This is especially true as researchers continue to compete for the resources necessary to continue their research and lobby legislators, foundations and government institutions for the continuation of support and the creation of new funding programs and initiatives (Renault, Cope, Dix, & Hersey, 2008).

However, as federal, state, and private institutions continue to expend scarce resources through grant programs and to develop policies and programs designed to enhance collaboration and produce cutting-edge research while increasing the competitive power and global impact of the research endeavors of the United States, it is also critical that we develop a better understanding of how our programs, institutional structures, and policies can facilitate and enhance the efficacy of collaborative efforts (Eddy, 2010; Kezar & Lester, 2009). Furthermore, as the drivers of research at our universities, it is interesting to note that we know very little about how the pressure to collaborate in scientific production affects faculty members' behavior

or ongoing development as researchers. Eddy writes, “Little research exists that discusses the added strain to faculty work that stretches roles to now include institutional collaboration” (p. 62).

An examination of the benefits and outcomes of collaboration make it clear that collaborative work is essential to research success in a rapidly expanding knowledge economy (Koschmann, Lewis, & Isbell, 2011; NSF, 2011; Ribes & Bowker, 2011). However, those metrics say nothing about how researchers can maximize their collaboration skills and effectively apply them to a research problem. Renault, Cope, Dix, and Hersey (2008) note that metrics of success, such as patents and publication numbers, are insufficient for informing policy and constructively changing researchers’ behaviors because metrics “are by-products of the activities that should be encouraged” (p. 102). In an era of accountability and scarce resources, it seems critically important that we also focus on how we can nurture and maximize those activities, such as effective engagement in collaborative research, that have proven to lead to desirable outcomes (Eddy, 2010; Kezar & Lester, 2009; Koschmann, Lewis, & Isbell, 2011).

While we may be able to assume that tomorrow’s researchers will understand the importance of collaborative research, we cannot assume that those same researchers will uniformly have the professional training, experience, and background that they need to maximize the benefits of their collaborative activities, or that they will be in a position to make informed choices on their training and development as future innovative researchers. This is especially true as the community within which researchers collaborate becomes more international and the collaborative activities themselves become more complex and challenging due to the increasing heterogeneity of the various actors and contexts in which knowledge resides. Emphasizing the important role that our institutions of higher education play in the development of faculty

members' collaborative skills, Eddy writes, "Faculty members are socialized for their roles during their time in graduate school (Austin, 2002); thus, the faculty role models present in research institutions have a large impact on the professions and on how new faculty members anticipate their roles" (p. 62). They go on to speak to the individual agency faculty members possess in the conduct of their research. This is possible due to their expertise on the one hand, and through their disciplinary networks with highly skilled colleagues on the other (Eddy, 2010).

As doctoral programs increase in length, the postdoctoral training period becomes ubiquitous across the disciplines, and the competition for academic positions continues to increase, early-career faculty members will have less time to transition to and achieve in their chosen careers (Jones, 2009; Jones, 2010[a]; Jones, 2010[b]. Federal agencies are already seeing the average age of their grant recipients increase. Empirical data indicate that the average age of innovation has increased significantly over the past century (Jones, 2010[b]). All of this suggests that doctoral programs, postdoctoral training opportunities, and faculty support programs have an obligation to ensure they are appropriately preparing faculty members for collaborative careers and supporting those collaborative activities as soon as they are in those careers.

This study uses national data to examine how the backgrounds of early-career faculty members relate to the types of collaborative activity they engage in. By subsequently talking with members of this population about how they came to be collaborative in their research, why they engage in different forms of collaboration, and how those different forms of collaboration help them to achieve their research goals, we gain insight into how individuals understand their own experience within the context of national data. We also gain a deeper level of understanding into the unique, complementary, and contradictory roles that researchers' doctoral programs, postdoctoral training programs, and early academic careers play in their development as

collaborative researchers. Furthermore, by talking with scholars directly, this study further develops our understanding of the relationship between collaborative activities and the products of their research efforts. Taken together, the findings of this mixed methods study inform the policies, programs, and actions of federal funding agencies, higher education institutions, mentors, and individual researchers alike and enable the proactive creation a community of skilled research collaborators prepared to work together in the discovery and innovation process.

Outline of the Dissertation

This dissertation is organized into six chapters. The introductory chapter is followed by a review of the relevant literature and an explanation of the theoretical framework used to guide the research questions, data analysis, and conclusions derived from that analysis. Specifically, the literature review provides an overview of what we know about the relationship between time in career, collaboration, and productivity. This discussion is critical to understanding why early-career faculty members were targeted for this study on collaboration processes. This is followed by a discussion of the growing role of the postdoctoral research experience as a mechanism for training highly skilled researchers for independent research. The changing demographics of the doctoral, postdoctoral, and faculty ranks are also discussed, reflecting the rapid internationalization of these populations and their high levels of productivity. A discussion of social network theory in general and Granovetter's (1973) strength of weak ties hypothesis in particular conclude the chapter. In particular, the possible interactions between mobility and collaboration are discussed and how that may relate to research productivity within the context of social network theory.

Chapter 3 provides a detailed description of the study's mixed methodological approach. This includes an overview of the SDR survey instrument, a description of the SDR sample population studied and variables used, and a detailed explanation of the quantitative analytical techniques employed and their rationale. Chapter 3 also provides a description of the sampling method used to identify participants for the open-ended interviews, the data collection and analysis procedures, and the methods used to verify results and ensure their trustworthiness. In Chapter 4, the results of the quantitative analysis are reported. Chapter 5 examines the results from the qualitative stage of the study. Interviewees' self-reported collaboration patterns and processes for collaboration, as well as motivations for and gains from collaborative activity are explored. Respondents' sense of their development as collaborative researchers are also examined, as well as their ongoing efforts to refine and expand their collaborative skills. The final chapter discusses the overall findings of the study, how those finding relate to social network theory and the weak ties hypothesis, as well as the role of institutions of higher education and agencies in supporting collaborative research in higher education research. The chapter concludes with an overview of the study's limitations, as well as areas for additional research.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews the literature that informs the study. It begins by exploring the complex relationship between age, collaboration, and productivity and the reason for selecting early-career faculty members for this study on research collaboration. As this study also focuses on faculty members' training and development as collaborative researchers, the changing landscape with regard to doctoral education and the postdoctoral research experience are discussed. Social network theory and its strength of weak ties hypothesis are also discussed as they have guided the development of the research questions, as well as the analysis of the study's results. Finally, as this study focuses its lens on early-career faculty members' country of origin, mobility and its possible relationship to collaboration are discussed , as well as how that may relate to research productivity within the context of social network theory.

Early-Career Faculty Members: The Relationship between Time-in-Field, Collaboration, and Productivity

Empirical evidence suggests that scientists working within the Science, Engineering and Health (SEH) disciplines make the transition from doctoral students to productive independent researchers relatively quickly, despite the barriers that they must inevitably face (Howe, 2008; Stephan and Levin, 1992). Research in the 1980s and 1990s indicated that productivity and original scientific contributions, as measured by publication numbers and the receipt of research prizes, peaked on average between the ages of 25 and 45 (Simonton, 1988; Stephan & Levin, 1992). While more recent research has shown that the average age of peak scientific productivity has steadily increased over the past century due to the increased 'burden of knowledge' (Jones, 2009; Jones, 2010[a]) and the longer training times necessary to prepare scholars for successful

independent research careers (Jones, 2009; Jones, 2010[a]; Kaiser, 2008), the relationship between innovative activity and age has been shown to be curvilinear with a steeper rise in productivity as scholars' move through their earlier years and then a gradual decline over time after productivity peaks (Jones, 2010[b]; Simonton, 1988; Stephan & Levin, 1993; Weinberg & Galenson, 2005).

The main concern related to the later onset of scholarly productivity is that productivity levels do not seem to have increased beyond middle age (Jones, 2010[b]). In Jones' (2010[b]) words, "The narrowing of the innovative life cycle reduces, other things equal, aggregate creative output" (p. 1). Efficiency in training and preparation for independent research careers, as well as developing mechanisms to enhance scholars' life cycle productivity are therefore of great concern to educators, independent researchers, and institutions that fund research alike. The outgoing message of National Institutes of Health (NIH) Director Zerhouni is a case in point. Zerhouni spoke urgently about the rising age of the average first-time NIH research grant recipients, which has crept up from 37 in 1980 to 42 in 2008, and called for a reprioritization in their grant programs toward early career scientists (Kaiser, 2008).

Part of the rationale for this push toward reallocating funding to early-career researchers can be found in the work of Weinberg and Galenson. Weinberg and Galenson (2005) examined the life cycle creativity of Nobel laureate economists and found significant differences in productivity and the type of innovation achieved by age. They found that Nobel laureates who are more conceptually oriented tend to produce their best work on average at age 25. Experimentally oriented Nobel laureates, however, tended to produce their peak work in their mid-50s. Their conclusion was that experience benefits experimental innovators while newness to a field tends to benefit conceptual innovators.

By providing young researchers with research support earlier in their careers, it is thought that they will increase their conceptual innovative productivity early on (Kaiser, 2008). This can then set the stage for researchers' later careers when they begin increasing their experimental innovative productivity as their knowledge and experience grows. Preliminary evidence from NIH's pilot effort to allocate more grants to early career scientists indicates that this population is just as successful in its research and just as likely to be competitive for future NIH funding as their better-established colleagues in the field (Kaiser, 2008).

There is another set of reasons for why researchers may be highly productive in their earlier careers. While the young may be naturally more adept at conceptual innovation in their early years (Weinberg and Galenson, 2005), they are also highly motivated toward scholarly productivity, especially if they are in academic careers that require research productivity to earn the security of tenure and the benefits of ongoing promotion. In addition to increasing the chances of earning tenure and promotion, high productivity in the early career can disproportionately affect a scholar's salary, prestige, as well as the number of competitive job offers that he or she receives from desirable institutions (Stephan & Levin, 1992).

High productivity among younger scientists is also seen as valuable by employers, largely because it is considered an indicator of future productivity (Stephan & Levin, 1992). No doubt this is one of the reasons research production is given such weight in the tenure review and ongoing promotion process (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). The younger the scientist is, the longer that productivity trend might last if the employer can retain the scholar (Stephan & Levin, 1992). Furthermore, as a younger scholar becomes established and recognized in the field, he or she develops a cumulative advantage that is externally reinforced over the course of his or her career.

Robert Merton called this the Matthew Effect, whereby scholars with an established reputation accrue greater recognition for their work than those who contribute equally but have not yet made their mark in the field (Merton, 1968). As Allison, Long, and Krauze (1982) put it, "Two publications of equal intrinsic merit will receive differential recognition if the authors are unequal in prestige" (p. 615). The cumulative benefits that an institution might derive from this differential recognition are potentially enormous. An institution of higher education, for example, may benefit from an eminent scholar's ability to attract grant funding, highly qualified graduate students, donations for a research program, or other productive research scholars looking to establish careers at institutions with high levels of innovation, connections, and research productivity (Stephan & Levin, 1992).

In light of the high-stakes competitive research environment tenure-track and newly tenured faculty members find themselves in, evidence of high productivity among SEH scientists early in their careers, the emphasis colleges and universities place on research in making tenure and promotion decisions, and the well-documented Matthew Effect, examining the development and application of collaborative research skills among early-career faculty members becomes critically important. Further emphasizing the importance of understanding collaboration within the context of research production in the SEH disciplines is an abundance of evidence indicating a high correlation between collaborative activity and scholarly productivity (Balog, 1979/80; Beaver & Rosen, 1978; Beaver & Rosen, 1979a; Beaver & Rosen, 1979b; Jones, 2010; Hodder, 1979/80; Katz & Martin, 1997; Lawani, 1986; Pao, 1980; Pao, 1981; Pravdic & Oluic-Vukovic, 1986; Price, 1963; Price, 1986; Price & Beaver, 1966). This correlation is undoubtedly due to a number of factors. Collaboration enables the efficient and cost-effective pooling of resources in the production of cutting-edge research (Katz & Martin, 1997); the sharing of information, skills,

and techniques among scientists working in related and/or complimentary areas of inquiry (Katz & Martin, 1997; Kuhn, 1970; Peters & Van Raan, 1989; Stefaniak, 1982); as well as quick and cost-effective access to specialized knowledge and equipment (Edge & Mulkay, 1976; Gordon, 1980; Jones, 2010; Price, 1986).

Illustrating the potentially critical role that collaboration plays in scientists' early careers, Pravdic & Oluic-Vukovic (1986) found that collaboration with highly productive scholars enhances personal productivity, while collaboration with less productive scholars tends to decrease personal productivity. Supporting Merton's concept of the Matthew Effect, research has also shown that publications with multiple authors tend to have higher acceptance rates (Gordon, 1980), as well as greater impact factors and recognition in the field (Jones, 2010; Lawani, 1986; Nudelman & Landers, 1972). Finally, emphasizing the importance of international collaboration in research productivity and recognition, research has consistently demonstrated that internationally co-authored papers have significantly higher impact factors than papers published by authors from a single country (Adams, Gurney, & Marshall, 2007; Narin and Whitlow,1990).

Taken together, this evidence suggests that early-career faculty members are highly motivated to develop the collaborative networks that could enhance their research productivity, original contributions to their field of inquiry, and recognition of those contributions by scholars in their disciplines (Jones, 2010). As detailed in Chapter 3, variables such as age, years since earning the doctorate, and tenure status have been deliberately included in the study in order to explore their relationship with collaborative activity.

The Postdoctoral Research Experience and Country of Citizenship

The Postdoctoral Experience

Simply recognizing the importance and potential of collaborative research and wanting to establish a set of beneficial collaborative partnerships do not in and of themselves result in the effective development and use of collaborative linkages, however. Thus, it is also important to examine the role of scholars' training in the development and fostering of collaborative research skills among early-career SEH faculty members (Brainard, 2005). Various approaches to training can be pursued by doctoral recipients seeking faculty careers, and this varies substantially by field of study (Hoffer, Grigorian, & Hedberg, 2008; Regets, 1998; Regets 2002). The postdoctoral research position, for example, defined by the National Science Foundation (NSF) [2006] as a temporary position awarded in academe, industry, a non-profit organization or government primarily for gaining additional education and training in research, would seem to be of growing importance as an intermediate step in scientists' transformation from high-potential doctoral students to highly productive and collaborative researchers in the SEH disciplines (Davis, 2005; Hoffer, Gregorian, & Hedberg, 2008; Nerad & Cerny, 1999).

The 'postdoc' was first established at Johns Hopkins University in 1876 as an optional way of acquiring advanced specialized skills in preparation for a faculty career (Graduate Employees and Students Organization [GESO], 2001). While these positions also served doctorates for a time as a way to stay employed in the field as the number of faculty jobs dwindled (Cantwell, 2009; Davis, 2005; National Postdoctoral Association, 2009; NSB, 2010), it is also becoming nearly ubiquitous and an increasingly essential developmental experience for those desiring research-related careers in the SEH disciplines (Cantwell, 2009). Between 1981 and 1997, for example, university postdoctoral numbers increased by 125% (GESO, 2001), and

between 1998 and 2005 overall postdoctoral numbers increased by another 21% (Regets, 2007). By 2005, over 50,000 postdoctoral scholars were employed across sectors in the United States (Brainard, 2005, Davis, 2005; Lee, 2001; NSB, 2010).

More recent postdoctoral scholar estimates by the National Science Foundation indicate that in 2009 there may have been upwards of 89,000 postdoctoral scholars in the United States (National Postdoctoral Association, 2009). Of these 50,000 to 89,000 positions, roughly 69 to 70% are federally funded with 74% of these federally funded positions in the life or health sciences, 22% in the physical sciences or engineering, and 4 % in social sciences or humanities (Davis, 2005; National Postdoctoral Association, 2009). Between 2002 and 2007, 45% of all U.S. Ph.D. program graduates began their careers with a postdoctoral appointment, up dramatically from only 31% in 1981 (Hoffer, Grigorian, & Hedberg, 2008).

The percentage of doctoral recipients who end up pursuing postdoctoral research opportunities varies substantially by discipline and sub discipline, but it is clear that the postdoc is fast becoming a standard career path in the sciences and engineering. For example, of those who graduated between 2001 and 2006, 57% of doctorates in the life sciences; 50% of those in the physical sciences; 21% in engineering, computer, and mathematical sciences; and 23% of doctoral recipients in the social sciences reportedly held at least one postdoctoral position in the past five years (Hoffer, Grigorian, & Hedberg, 2008). Furthermore, these numbers are rapidly increasing (Hoffer, Grigorian, & Hedberg, 2008; Regets, 1998). Engineering for example, reflected a 164% increase in the number of graduates who pursued a postdoctoral position (comparing the group who had graduated within 5 years of the 2006 Survey of Doctorate Recipients with all earlier cohorts), and computer/mathematical sciences postdoc numbers grew by 82% (Hoffer, Grigorian, & Hedberg, 2008).

Naturally, these numbers reflect an increase in the numbers of new faculty members who have had postdoctoral experience prior to taking on a tenure-track position. Illustrative of this point, 49% of all former postdocs were found to be employed in the education sector, mainly university and college appointments on the 2006 Survey of Doctorate Recipients (Hoffer, Grigorian, & Hedberg, 2008). Looking at census data collected by the American Chemical Society, Parr (2002) found that upwards of 71.4% of chemists working within academia have held a postdoctoral position (these numbers vary by sub discipline within chemistry. This number is consistent with the research university survey findings of the Association of American Universities (1998), which found that two-thirds of new assistant professors had held at least one postdoctoral position.

With regard to the productivity of postdoctoral researchers, a review of two issues of the internationally distributed journal *Science* revealed that 43% of the first authors were postdoctoral scholars (Vogel, 1999). The same study found that over a 10-year period, 75% of the papers published out of a Harvard Medical School lab were first-authored by postdoctoral researchers. Furthermore, data from the Sigma Xi national postdoctoral survey indicate that as training becomes more structured for postdoctoral scholars, their productivity, as measured by the number of research publications, increases significantly (Brainard, 2005; Davis 2009). This finding clearly points to the multifaceted connection between the postdoctoral experience, productivity, and training.

In terms of collaboration, 78% of postdocs who responded to the 2006 Survey of Doctorate Recipients (SDR) indicated that they work with an immediate group or team, 61% indicated that they worked with others in the same organization, 48% indicated that they worked with others in another U.S. organization, and 19% indicated that they collaborated with scholars

abroad (Foley, 2010). This is despite the fact that these scholars tend to be in more controlled research environments where a higher level of supervision is the norm (Åkerlind, 2005; Brainard, 2005; Davis, 2005; Davis, 2009; Freeman, 2001; Graduate Employees and Students Organization, 2001). These data suggest that the higher levels of supervision expected for postdoctoral mentees do not necessarily result in collegial isolation within the knowledge economy. Postdoctoral scholars seem to be collaborating at high levels despite their general lack of independent researcher status.

Emphasizing this last point, data from the 2005 Sigma Xi Postdoc Survey suggest that postdoctoral researchers not only collaborate broadly in the production of their research, but that they are beginning the process of transitioning to more independently generated collaboration. For planning new research projects, for example, only 8% of respondents to the Sigma Xi survey indicated complete control over the planning of new research projects (Davis, 2005). Another 17% felt that they were mostly in control of new project planning. However, the data on collaboration show a possible appropriation of control in this area. Forty-six percent of respondents (13,810 of 29,890) to the 2006 SDR indicated that their current postdoctoral position increased their contacts with colleagues in the field to a "great extent" (NSF, Division of Science Resources Statistics, 2006). Furthermore, 17% of respondents on the Sigma Xi survey indicated that they felt in complete control of whom they choose to collaborate with and an additional 29% reported that they are mostly in control of whom they collaborate with. These findings corroborate those from other data on the Sigma Xi survey. Both U.S. citizens (36.4%) and temporary visa holders (39.2%) indicated that the development of opportunities to collaborate with researchers in the field other than their postdoctoral supervisor were "very important" (National Postdoctoral Association [NPA], 2005). Respondents also indicated that the

opportunities for collaboration with people other than the supervisor were a "very important" reason for choosing their current position over their next best employment option (NPA, 2005).

Clearly, collaboration plays a critical role in the professional lives of the highly productive SEH workforce. What we do not now know, however, is how uniquely formative the postdoctoral experiences are in terms of defining the nature and extent of future collaborative work. As postdoctoral researchers go on to pursue independent research careers as faculty members in the SEH disciplines, do they have an advantage in the realm of collaborative activity over those faculty members who have not had a postdoctoral research experience? Clearly training does not end with the postdoctoral position. Many faculty members, for example, receive support from peers and more senior colleagues as they develop their independent research programs and begin to assemble their tenure and/or promotion dossiers (de Janasz & Sullivan, 2004; Diggs, Garrison-Wade, Estrada, & Galindo, 2009; Jacelon, Zucker, Henneman, & Stacciarini, 2003; Knippelmeyer & Torraco, 2007; Mentors Peer Resources, 2010; Mullen & Hutinger, 2008; Pololi, Knight, Dennis, & Frankel, 2002). As the data on age and life-cycle productivity also suggest, the kind of productivity may change over the course of a scholar's life with conceptual innovations coming earlier in the career and experimental innovation and its associated products coming later on as a person's human capital accumulates (Weinberg and Galenson, 2005). These issues are explored in both the quantitative and qualitative stages of the study.

It should also be pointed out that the postdoctoral experience is not the only way that new faculty members can develop their collaborative research skills prior to beginning their faculty careers. Many faculty members, for example, collaborated with their faculty mentors as students and were included in their mentors' research projects, as well as in the extensive collaborative

networks those mentors had built over time (Cole, 2009; Lei & Chuang, 2009). Thus, we must acknowledge that new faculty members may have had a variety of training experiences over the course of their graduate, postdoctoral, and faculty careers that may have contributed to the development of their collaboration skills. By combining survey data from the SDR and data from semi-structured interviews with faculty members, new insights are gained as to what those key experiences are and their relative importance in terms of informing the individual researcher's perceptions of and involvement in collaborative research activities.

Country of Citizenship

The reason for comparing the development of collaborative activity among U.S.-based faculty members is that international doctoral program graduates undeniably make increasingly substantial contributions to U.S. research interests. Temporary U.S. resident international students received 36% of all science- and engineering-related doctorates awarded in the U.S. in 2005 and more than half of the doctorates in engineering, mathematics, computer sciences, physics, and economics in that same year (Lee, 2001; NSB, 2008). The National Science Board (2008) also reports that nearly all the recent growth in the number of science and engineering doctorates earned in the U.S. is attributable to temporary U.S. residents. Indeed, U.S. census data between 1990 and 2000 show that the percentage of international doctorate-level workers in the science and engineering sector of the U.S. increased from 24% to 38% (NSB, 2003; Tremblay, 2005). In fact, a majority (55–57%) of U.S.-based postdoctoral researchers are temporary U.S. visa holders (GESO, 2001; NSB, 2008; NSB, 2010; Regets, 2007[b]).

Beyond the doctoral and postdoctoral ranks, demographic studies have shown that at least 16.9% of new entrants to faculty jobs and 11.5% of those in senior faculty positions are foreign-

born (Howe, 2008). Furthermore, at research universities, 26.6% of new entrants and 17% of senior faculty are foreign-born (Howe, 2008). Emphasizing the rapid growth of this international faculty population, the National Center for Education Statistics reports that between 1993 and 2003 non-resident alien full-time faculty numbers grew by an astonishing 96.3% (Howe, 2008).

In addition, this population of U.S.-based researchers has been shown to contribute substantially to U.S. research and innovation efforts (Stephan & Levin 2001; Wadhwa et al., January 2007; Vogel, 1999). No doubt this is due in part to the fact that immigration regulations related to permanent residency largely favor the highly skilled, as well as scholars who have substantial publication and presentation records, have received national awards for their research, and can show evidence of other scholars citing their work and seeking their expert opinions. Taken together, the increasing prevalence and substantial contributions of this population suggest that it is important to understand how this population conducts its collaborative research and where they obtained their skills at collaboration. This can not only inform our understanding of how to best prepare doctoral students and postdoctoral trainees for competitive research careers in a global knowledge economy (e.g. encourage doctoral students to spend some time conducting research in a non-U.S. environment), but may inform the policies of federal agencies and other institutions that support U.S. research efforts. Many grant programs, especially federal grants through institutions like NSF and NIH, are unavailable to U.S.-based researchers who do not have U.S. citizenship or permanent residency status (Åkerlind, 2005).

Theoretical Framework

The focus of this stems largely from the theoretical foundation used to frame the research questions and data analysis, as well as from the increasing prevalence of international scholars in

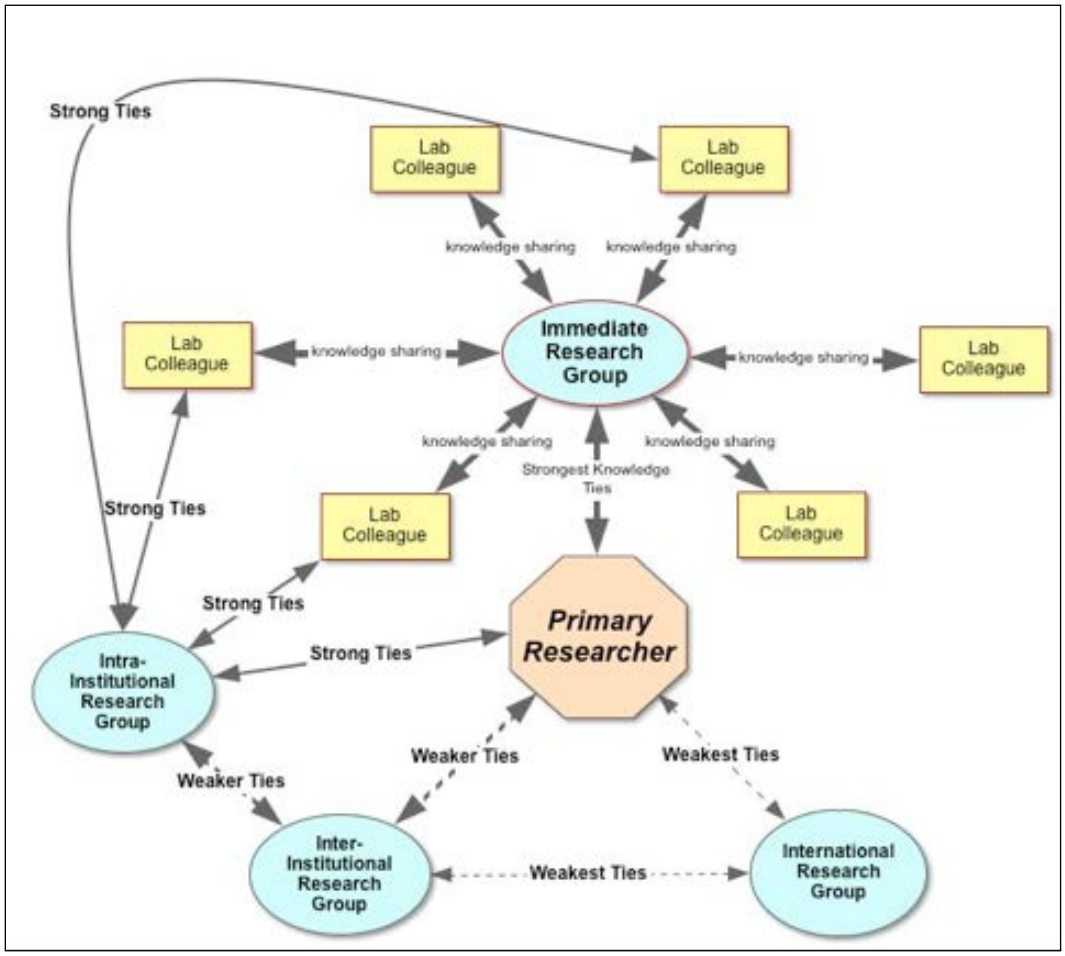
the United States studying and working in the science, engineering, and health disciplines. Social network theory and the strength of weak-ties hypothesis (Burt, 1992; Granovetter, 1973; Granovetter, 1983) have been used to guide this study. The exchange and production of new knowledge has been shown to rely heavily upon the interdependent social network ties (social capital) that an individual develops over his or her life (Burt, 1992; Eddy, 2010; Granovetter, 1973; Granovetter, 1983; Jones, 2010; Portes, 1998) [See Figure 2.1]. With the increasingly global nature of the knowledge economy and the rising importance of accessing people and the scholarship that they produce beyond an institution's or even a country's borders (Jones, 2010), the question is explored as to whether or not foreign-born faculty members have a greater number of interdependent ties with scholars within their institutions, beyond their institutions, and beyond the U.S.

The strength of weak ties hypothesis predicts that it is the novel information that we gain from outside our normal day-to-day collegial networks that has the potential to contribute substantially to the production of innovative scholarship. Chubin (1976) points out that all scientific fields have a center and a periphery where the periphery is defined by its members' weak ties to the center and to other relevant scientific groups. He writes, "If the innovativeness of central units is shackled by vested intellectual interests (or perspectives) then new ideas must emanate from the margins of the network" (Chubin, 1976, p. 460).

Researchers rely upon colleagues within their immediate environment to share their ideas, receive feedback, and ensure that they are appropriately applying the knowledge that they are familiar with to the research problem at hand. This form of interaction is characteristic of what Granovetter refers to as strong ties. Particularly characteristic of strong ties is the relatively closed nature of the knowledge network and the redundancy of the information that is shared

over time (what Chubin refers to above as “vested intellectual interests” (1976, p. 460). In Figure 2.1, strong ties are articulated by the immediate research group and the strong ties between the primary researcher and his or her colleagues within the lab. This is the strongest set of ties for the primary researcher, followed by the ties s/he and her/his immediate colleagues share with others from the same institution (intra-institutional research groups). Granovetter characterizes this “habit of mind” as reflective of an “absence of flexibility” (Granovetter, 1983, p. 205). By this he means that once the core knowledge of the more immediate group has been accessed and applied to the research problem, new information is harder to come by and less likely to be actively sought after and incorporated. As a result, innovation has the potential to become stagnated.

Figure 2.1. **Social Network Theory and the Strength of Weak Ties Hypothesis**



The strength of weak-ties hypothesis would also suggest that U.S.-based scholars with looser ties to scholars outside their immediate network of colleagues would be better leveraged to access new information and innovation that exists beyond their close circle of colleagues (Burt, 1992; Eddy, 2010; Granovetter, 1973; Granovetter, 1983; Portes, 1998). As Eddy (2010) writes, "For networking, faculty members can act as the node to connect disparate networks. As Granovetter (1983) noted, it is often these types of weak ties that help create the types of networks required to make partnerships succeed, as they bring together individuals outside the limited range of a tight network" (p. 64).

The connections of the primary researcher to colleagues on an inter-institutional level or an international level may be fairly tenuous. In Granovetter's words, each of us has a collection of close connections or a "densely knit clump of social structure" (1983, p. 202), but each of those colleagues has their own dense social structure within which they operate that is distinct from that of the primary researcher's. Colleagues, therefore, serve as links between densely knit social structures. The primary researcher may have to rely upon such a colleague to gain access to knowledge networks beyond his or her local context in the pursuit of needed knowledge, expertise, and/or resources. That mediated connection (shown in Figure 2.1 by the dotted lines) between the primary researcher and the inter-institutional or international research group is what defines weak ties, and it is the resultant knowledge sharing between distinct and separate knowledge centers that Granovetter refers to when using the term "strength." In Granovetter's words, "The weak tie between Ego (the primary researcher in this case) and his acquaintance, therefore, becomes not merely a trivial acquaintance tie but rather a crucial bridge between the two densely knit clumps of close friends…It follows, then, that individuals with few weak ties

will be deprived of information from distant parts of the social system and will be confined to the provincial news and views of their close friends" (Granovetter, 1983, p. 202).

Foreign-born faculty based in the U.S., by nature of their own mobility, are believed to be more likely to have weak ties with scholars in other countries than their U.S. counterparts who have earned their degrees in the U.S., possibly pursued postdoctoral research opportunities in the U.S. and continue to work in the U.S. as faculty members. Indeed, research on the brain circulation phenomenon, in which highly skilled expatriates continue to contribute their human capital to their countries of origin, has shown that international scholars working in their adopted countries can and do maintain personal connections with their source countries, suggesting an accumulation of lasting ties through mobility (Cheng & Yang, 1998; Kahn & MacGarvie, 2008; Regets, 2007[a]; Saxenian, 2002; Szelényi, 2003). In a related fashion, Granovetter (1983) found a strong link between mobility in employment and the number of weak ties that an individual possesses. Weak ties, in fact, were found to be more influential in job mobility than the number of strong ties that an individual possessed. The implications of this finding for the current study are obvious. International mobility to pursue a doctoral degree, postdoctoral research experience, and a faculty career in the United States may be related to the number of weak ties that an individual has to their dense social networks in their home country as well as those in the United States. These ties can be used, after all, to find doctoral programs, identify postdoctoral positions, and to secure a faculty position. It stands to reason, therefore, that these same weak international ties could be subsequently used to connect the scholars to other scholars outside the United States. In other words, it is predicted that foreign-born faculty members working in the United States will have more weak ties with colleagues abroad than their domestic colleagues and will make use of these weak ties in their research production.

There is some reason to question the assumption that faculty members with international status are likely to be more collaborative internationally, however. In his book on the American research university, for example, Cole (2009) makes the point that what makes the American research university unique is its distinct tradition of collaborative work in the lab where faculty members and students work together in a team. Cole contrasts this with the more hierarchical German tradition in which the "*Geheimrat,*" or "great scientific leader" serves as the person in charge of a group of subordinates (2009, p. 27). Depending upon the cultural and research traditions that international faculty members come from and identify with, it is conceivable that they may be less inclined to collaborate with others, especially in their early careers when their sense of subordinate status may be more exacerbated. The degree to which an international faculty member identifies with the American collaborative research tradition or another more hierarchical research tradition may also relate to when the person came to the United States for study. These are issues explored in this study. The next chapter explains the overall methodological approach of this dissertation, as well as the specific quantitative and qualitative methodologies that were employed.

CHAPTER 3: RESEARCH METHODS

As explained in the pages that follow, a sequential transformative strategy (Creswell, 2003) has been used to guide this mixed methods study. In describing the sequential transformative approach, Creswell (2003) asserts that priority can be given to either the quantitative or qualitative stage, but that it is theory that guides the study, rather than the choice of a particular method of inquiry. Creswell (2003) explains:

> The purpose of a sequential transformative strategy is to employ the methods that will best serve the theoretical perspective of the researcher. By using two phases (a quantitative stage and a qualitative stage), a sequential transformative researcher may be able to give voice to diverse perspectives, to better advocate for participants, or to better understand a phenomenon or process that is changing as a result of being studied (p. 216).

Due to the socially constructed nature of knowledge (Marginson, 2009; Merriam, 1998) and the highly personal nature of how, when, why, and to what effect an individual conducts collaborative research, the qualitative stage of this study has been given primacy. However, the quantitative stage of this research was critically important in establishing the parameters for the semi-structured interviews that follow and in determining the direction of the questioning.

Strategy of Inquiry

Couched within the context of social network theory, the quantitative component of this study uses a national data set to identify the forms of collaboration that U.S.-based faculty members are engaged in and to identify the factors that best account for observed variability in faculty members' collaboration patterns. The qualitative component of the study makes use of

interviews to explore how individuals' collaborative experiences and practices relate to the quantitative findings of the study. The interviews are also used to move beyond inferences derived from national data so as to examine participants' motivation for engaging in collaborative activity; how they work to develop, enhance, and maintain that activity; and how they see themselves engaging with a network of other researchers. Furthermore, the interviews examine the degree to which participants attribute their development as collaborative researchers to their doctoral student and postdoctoral training experiences, to their countries of origin, to their fields of research, and/or to the demands placed on them as tenured/tenure-track faculty members pursuing independent research careers. Finally, the qualitative portion of this study enables an exploration of how U.S. citizen and non-U.S. citizen faculty members differ or do not differ in their perception of the constraints on or parameters of their collaborative activity. Specific attention will be paid to the perceived role of faculty members' immigration status as it relates to the development of the four types of collaborative activity defined on the 2006 SDR (team-centered, intra-institution, inter-institution, and international). This is described in more detail in the pages that follow.

Merriam (1998) notes that all qualitative research is grounded in the idea that reality is socially constructed by individuals. Reality, therefore, inherently stems from and is informed by people's experiences (Merriam, 1998). This gets at the heart of the reason for using a sequential transformative strategy (Creswell, 2003) to develop a better understanding of SEH researchers' motivations and mechanisms for their collaborative mode of inquiry; the acquisition of those skills; as well as the use, maintenance, and understanding of that collaborative activity. As the process of conducting qualitative research and analyzing data is necessarily interpretive, the end goal of this study is not to deductively develop a set of conclusions or test a set of objective and

quantifiable hypotheses developed from a theory, but to inductively develop an understanding of the meaning researchers ascribe to their own collaborative behavior while using social network theory and national data to define the scope of the inquiry and to frame the context for a set of subjective conclusions (Creswell, 2003). In distinguishing qualitative inquiry from entirely deductive processes Merriam writes:

> Qualitative research *primarily employs an inductive research strategy*. That is, this type of research builds abstractions, concepts, hypotheses, or theories rather than tests existing theory. Often qualitative studies are undertaken because there is a lack of theory, or existing theory fails to adequately explain a phenomenon. There are thus no hypotheses to be deduced from theory to guide the investigation. Qualitative researchers build toward theory from observations and intuitive understandings gained in the field. In contrast to deductive researchers who "hope to find data to match a theory, inductive researchers hope to find a theory that explains their data"(Goetz & LeCompte, 1984, p. 4) [p. 7].

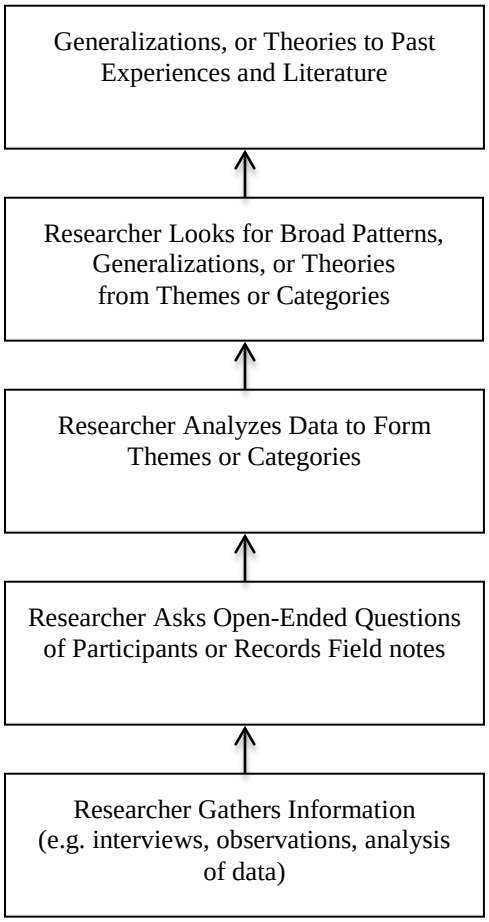
Using an inductive process, the sequential transformative strategy (Creswell, 2003) enables the researcher to move from data (2006 SDR data) and general observations to targeted lines of inquiry (interviews), the development of grounded themes and categories (analysis), and the elaboration of theory (social network theory). Figure 3.1 shows how Creswell depicts this process.

Quantitative Methodology

For this stage of the study, national data were analyzed. This corresponds with Creswell's first stage of the inductive process of a larger qualitative study (Figure 3.1): gathering

information in preparation for a set of open-ended interviews that follow. As mentioned in Chapter 1, there were two main research questions that guided this preliminary portion of the study.

Figure 3.1. The Inductive Logic of Research in a Qualitative Study



Adapted from: Creswell, 2003, p. 132.

Those questions are:

- *What forms of collaborative research activity are most representative of early-career faculty researchers working in the U.S.?*

- *What factors predict early-career faculty researchers' participation in collaborative activities, with particular attention to the unique effects of field of study, institutional type, postdoctoral research experience, and/or international faculty status?*

Survey of Doctorate Recipients

The Survey of Doctorate Recipients (SDR) is the source of the national data used to evaluate the forms of collaborative activity that early-career faculty researchers in the United States are engaged in and the factors that predict those forms. The SDR is a longitudinal survey that follows a sample of doctoral recipients who indicated an intention to remain in the U.S. after graduation, continued to live in the U.S. when the survey was administered, and were working in the fields of science, engineering and health. NSF only includes respondents under the age of 76 in the SDR. The SDR is administered every two years and in 2006 consisted of 42,955 cases. The overall sampling rate for the SDR is 5.5% of those U.S. doctorate earners who completed the Survey of Earned Doctorates upon program completion and indicated an intention of remaining in the U.S. after graduation. The 2006 SDR was selected for this study because it is the first year that NSF asked respondents specific questions about who they collaborate with in the U.S. and abroad.

Sampling weights are used by NSF to correct for potential bias due to unequal selection. According to NSF, this is done in three stages: 1) a base weight is calculated for every case in the sample to account for its selection probability under the sample design, 2) an adjustment for unknown eligibility is made to the base weight by distributing the weight of the unknown eligibility cases to the known eligibility cases proportionately to the observed eligibility rate within each adjustment, and 3) an adjustment for nonresponse is made to the adjusted base

weight to account for the eligible sample cases for which no response was obtained. The weighted response rate for the survey in 2006 was 78% and item nonresponse rates ranged from 0.0% to 3.6%. for personal demographic data such as marital status, citizenship, and race.

Sample Population of the Study

Within the SDR, respondents meeting the study's selection criteria were filtered out for analysis. As this study focuses on collaboration among newer faculty members, the sample includes those who received their doctorates up to ten years prior to completing the 2006 SDR. This ten-year timeframe was also used by Nerad and Cerny (1999) in their national study (supported by the National Science Foundation and Mellon Foundation) of doctoral recipients' career patterns. As the SDR is administered every two years, this allows for the inclusion of up to five doctoral program completion cohorts. This also allows for the inclusion of a majority of those faculty members who have had a postdoctoral training experience between their doctoral programs and the start of their independent faculty careers (Nerad & Cerny, 1999). Ninety-six percent of 2006 SDR respondents who completed a postdoctoral training experience held only one or two postdoctoral appointments, and the average total length of time in postdoctoral status has consistently been shown to range from 2.4 to 5 years (Brainard, 2005; GESO, 2001; Nerad & Cerny, 2002), depending upon the field of study.

Within the population selected for inclusion in the study, respondents included those who were employed by a four-year college or university, medical school, or university-affiliated research institute who also held the faculty rank of Assistant Professor or Associate Professor at the time the 2006 SDR was completed. An additional selection criterion included tenured or tenure-track status. By defining the study population this way, it was possible to examine the

early career collaboration patterns of new faculty members at a time when they are experiencing the pressures of developing a strong research portfolio toward tenure and/or promotion (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). By including SDR respondents ten years out from their doctoral programs who are pursuing highly competitive independent faculty careers, it is also possible to examine how researchers' field of study, institutional type, gender, choice of whether or not to pursue a postdoctoral research appointment, and immigration status relate to collaboration habits. After weighting the cases using the NSF-provides weighting variable (WTSURVY), the 2006 SDR has 47,849 respondents who meet these criteria.

Dependent Variables

As mentioned in Chapter 1, for the purposes of this study collaboration has been defined broadly as working with other scholars in the performance of research. This definition is inclusive of all types of professional collaboration, both near and far, and comports well with the survey instrument used by NSF in 2006. As the purpose of this study is to examine individuals' patterns of collaboration, as well as the perceptions of the role, development, and application of collaboration skills, rather than on the outcomes of those collaborative efforts, outcome variables were not included. Specific outcome variables, such as patent and publication numbers, while typically available, are not on the 2006 SDR.

The dependent variables representing the forms of collaboration examined at this stage of the study were derived from the section of the 2006 SDR on collegial work patterns. This section is comprised of a series of dichotomous variables. These included: work with an immediate work group/team (WKTEAM), work with others in the same organization but not the same group/team

(WKSORG), work with individuals in other organizations in the U.S. (WKUSORG), and work with individuals located in other countries (ICOLLAB). The 2006 SDR instructed respondents to indicate whether or not they engaged in each type of collaborative activity separately and does not treat them as mutually exclusive categories. Therefore, it was possible for a respondent to indicate that they had engaged in any or all forms of collaboration. A list of the dependent variables and their definitions has been provided in Table 3.1.

Specific sub-forms of collaborative activity were not available for all four types of collaborative work activity surveyed on the 2006 SDR. While previous versions of the SDR and subsequent versions of the SDR did ask respondents specific questions about collaboration in the authoring of papers, articles, books, and monographs, these questions were not specifically broken out by the location of the collaborators in 2006. The qualitative stage of the study asks informants specific questions about the types of collaborative projects they engage in and how the type of project (e.g., writing a conference paper, preparing an article for publication, authoring a book) affects the choice of who to collaborate with based on the four types of collaborative activity included on the 2006 SDR.

Independent Variables

The primary independent variables included respondents' international or domestic citizenship status as faculty members, their decision to pursue or not pursue a postdoctoral training position prior to pursuing faculty careers, and field of study. Respondents' immigration status was determined by whether they indicated "U.S. citizen" or "Non-U.S. citizen" on the SDR (CTZUSIN). The rationale for using citizenship as the categorical variable, rather than respondents' immigration status is the fact that the non-citizen status includes researchers who

are in either non-immigrant status (e.g. H-1B, F-1, J-1, TN, O-1) or immigrant status (permanent residents). Pooling non-immigrants and immigrants together bolstered the sample size and differentiated this group of early-career faculty members from those researchers who had either been born in the United States, or were naturalized earlier on eligibility grounds unrelated to degree-specific employment in a highly skilled area. Employment-based naturalization (through competitive selection for a permanent job) and family-based naturalization (through marriage to a U.S. citizen) to U.S. citizenship status are both lengthy processes that require the obtainment of permanent residency first (a one- to five-year process, depending on country of origin and type of employment-based immigrant petition), and a five-year period of time in permanent resident status prior to obtaining eligibility to apply for naturalization to U.S. citizenship status. International students who graduate from U.S. doctoral programs are unlikely to obtain U.S. citizenship status within ten years of program completion as students on student visas and postdoctoral researchers are both ineligible for permanent resident status on the basis of their primary activity. Of the 2,428 respondents studied, 1,957 (81%) were U.S. citizens and 471 (19%) were Non-U.S. citizens.

The second primary independent variable included in the study relates to the decision to pursue or not pursue postdoctoral training. Postdoctoral training is fast-becoming ubiquitous in the physical and life sciences and is growing exponentially in the engineering disciplines, although the overall levels in engineering are still relatively low (Hoffer, Grigorian, & Hedberg, 2008; Regets, 1998; Regets 2002). While it is true that as the burden of knowledge increases so too do the length of doctoral programs, the degree of specialization within disciplines, and the necessity of a postdoctoral training period (Jones, 2009; Jones 2010[a]), it cannot be taken for granted that a postdoctoral training period enhances a researcher's ability to conduct and benefit

from collaborative research. It is quite possible that faculty members without postdoctoral research experience collaborate equally well, in the same fashion, and to the same effect as their counterparts who have pursued postdoctoral research appointments. The value-added impact of the postdoctoral period on scholarly engagement and productivity is an important consideration for funding agencies like NSF and NIH, which contribute millions of U.S. dollars to support the hiring and development of postdoctoral researchers.

To determine if respondents had a postdoctoral research position prior to beginning their faculty careers, a new variable, POSTDOC, was constructed as a dichotomous variable from the SDR data. The original survey variable, PDIXS, indicated the number of postdoctoral research appointments held by each survey respondent. Those without postdoctoral histories who had indicated "zero" on the survey became "no" responses for the newly constructed POSTDOC variable. All responses on the PDIXS variable that were greater than "zero" became "yes" responses for POSTDOC.

The last primary independent variable included in the study was field of doctoral study (NSDRMED). Field was broken down into four general categories: physical sciences, life sciences, engineering, and social sciences. This enabled an exploration of collaborative activity for significant differences between broad disciplinary groups since the sample sizes for many individual fields are too small to be included on their own. Field is an important variable to consider when looking at collaboration for a number of reasons. First of all, the rate of increase in collaborative work leading to scholarly publications and patents has been shown to differ substantially by broad fields (Jones, 2010 [a]; Wuchty, Jones, & Uzzi, 2007). While 170 of 171 science and engineering subfields and 54 of 54 social science subfields reflected a 15-20% increase in team size per decade on publications and patents, the percentage of team publications

(and therefore the base from which that growth occurs) differs by broad discipline (Jones, 2010 [a]; Wuchty, Jones, & Uzzi, 2007). Illustrative of this point, while 80% of science and engineering publications had multiple authors or inventors, only 50% of social sciences publications had multiple authors by 2005 (Jones, 2010[a]). Furthermore, recent data show that the share of international collaborations, the publication output emerging from those collaborations, and the impact factors of those publications differ significantly by both field of specialization and the countries involved in the collaborations (Adams, Gurney, and Marshall, 2007; Adams, King, & Ma, 2009; Jones, Wuchty, & Uzzi, 2008; Jump, 2010).

In addition to the three primary independent variables, other independent variables such as age (AGE), gender (GENDER), and Carnegie Classification (CARNEG) were examined to assist with the identification of characteristics for prospective participants in the qualitative stage of the study. Gender has been shown to be a significant factor in studies examining research productivity (Davis, 2005); career path, such as whether or not to pursue a postdoctoral research appointment (Lee, 2001; Nerad & Cerny, 1999); and how an individual copes with the challenges and pressures of an academic career (Lee, 2001). Age, on the other hand, has been shown to be a significant factor in academic production. The age of productivity in the sciences has been steadily increasing over the past century, just as training time and the burden of knowledge have been shown to increase (Jones, 2009; Jones, 2010[a]). Indeed, data from NIH indicate that the average age of first-time NIH grant recipients has increased from 37 in 1980 to 42 in 2008 (Kaiser, 2008). The later onset of innovative accomplishment among researchers has resulted in a 30% drop in lifetime productivity since the beginning of the 20th Century (Jones, 2010[b]). This drop comes in spite of evidence that suggests innovative activity is greater at a younger age, forming a curvilinear production curve over a typical researcher's career (Jones,

2010[b]; Simonton, 1988; Stephan & Levin, 1993; Weinberg & Galenson, 2005). It should also be noted that age distribution differs significantly by field (Stephan & Levin, 1993; Weinberg & Galenson, 2005), perhaps creating a significant interaction effect between field of study and age related to collaboration.

Respondents' institutional Carnegie classification (CARNEG) was also included as an independent variable to determine the extent to which the types of collaborative activities are predicted by the type of institution an individual is employed by (e.g. Research 1, Doctorate Granting 1, et cetera). This variable was included due to this study's focus on the individual researcher, his or her behavior, and the motivations behind that behavior. Each institutional type places differing emphasis on the relative importance of teaching and research with regard to tenure and promotion. This may affect the types of collaborative engagement faculty members pursue in the research portion of their careers. Faculty members working at an institution that prioritizes teaching, for example, may have different underlying motivations for and against collaboration in their research.

Two additional independent variables were also included with age to help develop an understanding of the complexity of time-related factors related to collaboration. The first of these was the number of years since earning the doctorate (DEGREEYRS). This variable was constructed by calculating the number of years that had accrued between the date of earning the doctorate (SDRYR) and when the SDR was completed. Given broadness of the age range of the graduate population within the United States and that of early-career faculty members, examining collaboration by the number of years since earning the doctorate enables a more detailed exploration of the relationship between time and experience since earning the degree, and collaboration, regardless of the age of the survey respondents. Similarly, tenure status

(TENSTA) was included in the study to determine if a unique relationship exists between a positive tenure decision and collaborative activity irrespective of the time that had elapsed since earning the doctorate or age. A variety of personal and professional reasons may legitimately delay when a faculty member goes up for tenure review, even as they continue to age and move farther away from their time in graduate school. A list of the independent variables and their definitions has been provided in Table 3.1

Table 3.1

Variable List

DEPENDENT VARIABLES		
Variable Name	**Variable Description**	**Type**
WKTEAM	Work with an immediate group or team	Categorical (yes / no)
WKSORG	Work with others in the same organization (company, university, agency, etc.), but not the same group or team	Categorical (yes / no)
WKUSORG	Work with individuals in other organizations in the U.S.	Categorical (yes / no)
ICOLLAB	Work with individuals located in other countries.	Categorical (yes / no)

INDEPENDENT VARIABLES		
Variable Name	**Variable Description**	**Type**
CTZUSIN	U.S. citizen or Non-U.S. citizen on April 1, 2006	Categorical (U.S. / Non-U.S.)
TENSTA	Tenure Status	Categorical (yes / no)
POSTDOC	Postdoctoral history	Categorical (yes / no)
SDRYR	Year earned the doctorate degree	Continuous (Year)
NSDRMED	Major field of U.S. doctoral degree	Categorical (Engineering, Social Sciences, Physical Sciences, Life Sciences)
AGE	Age at the time of survey completion	Continuous (Age)
GENDER	Respondents gender	Categorical (female / male)
CARNEG	Carnegie Type	Categorical (Carnegie typology)

Statistical Methods

As mentioned, a series of four dichotomous collaboration variables from the 2006 SDR were selected as dependent variables for analysis (WKTEAM, WKSORG, WKUSORG, ICOLLAB). After the respondent selection criteria were applied and the appropriate subpopulation was filtered out in SPSS, frequency analyses were conducted to determine the prevalence with which early-career faculty members engage in each of the collaborative activities highlighted on the SDR.

After examining the patterns of collaborative behavior among the different study subpopulations, a regression model was constructed. For the SDR, the dependent variables are dichotomous and the independent variables are a combination of continuous and categorical. Therefore, binomial logistic regression was used for the analysis. Logistic regression was used to predict the likelihood of a positive occurrence in the dependent variables relative to the likelihood of a non-occurrence in the dependent variables based on responses to each of the independent variables included in the study (Pampel, 2000). The basic logistic regression formula that guided these analyses was:

$$\mathbf{ln} = \mathbf{b_0} + \mathbf{b_1X_1} + \mathbf{b_2X_2} + \mathbf{.....} + \mathbf{b_{\#}X_{\#}}$$

Key

- **ln** = the natural log of the odds of the dependent variable occurring or not (i.e. a logit variable). The regression model, therefore, estimates the odds of an event occurring by calculating changes in the log odds of the dependent variables.
- $\mathbf{b_0}$ = the constant
- **X** = the independent variables
- **b** = the regression coefficients

For these analyses, the 4 separate dichotomous dependent variables were used in 4 different logistic regression analyses. The same independent variables were used in each of these analyses.

Qualitative Methodology

The overarching goal of the qualitative component of the study is to understand how individual faculty members in the SEH disciplines view their experiences and development as collaborative researchers, why they feel that such collaborative engagement is important to their work, and when they choose to be collaborative in their scholarship. Social network theory and the strength of weak-ties hypothesis form the theoretical lens used to guide this study's sequential transformative strategy (Creswell, 2003).

Organizational Categories

As mentioned in the introduction, four broad organizational categories or topics guided the participant interviews. These categories facilitated the process of developing and organizing themes from the interviews and situating these themes within a set of theoretically- and substantively-grounded categories as informed conclusions were developed (Maxwell, 2005). The broad organizational topics included:

- *What forms of collaboration are participants engaged in with regard to their research activities?*
- *What are the mechanisms early-career faculty members employ in the development of their collaborative research networks, how are these networks maintained, and why are collaborations pursued?*

- *What is the perceived relationship between the collaborative work done in graduate school, the postdoctoral research period (if applicable), and the respondents' faculty careers?*
- *Do faculty members with international status and domestic status differ in how they perceive the constraints on and opportunities available to them as they relate to the development of collaborative partnerships?*

These four organizational categories served as the conceptual bridge between the quantitative stage of the dissertation and the theoretical objective of locating faculty members' perceptions of their collaborative activity within the context of social network theory. The first organizational category enabled us to situate the respondents within the context of the SDR data by exploring the types of collaboration interviewees engaged in for their research. The second organizational category enabled participants to depart from what we know from the 2006 SDR and delve into their personal reasons for initiating different forms of collaborative research activity, examine how they maintain their collegial ties over time, and explore their personal role as both researcher and resource person within the context of a knowledge economy (i.e. how they negotiate the multifaceted role that they play within the research community.

The third topic facilitated an exploration of the sequential and/or cumulative effects of the training that they had received at different points of their development as collaborative scholars. This topic in particular goes beyond the study's theoretical framework, which situates collaborative activity within the context of acquiring (and reciprocally providing) new knowledge from outside one's immediate knowledge sphere, to the acquisition of the skills necessary to function effectively in such an environment. Therefore, this topic assumes that the research world (at least as it pertains to the SEH disciplines) is collaborative by nature and

focuses entirely on the substantive nature of how one develops the necessary collaborative research acumen. This step is critical in moving from a study that only informs our understanding of theory, to one that also informs national and institutional policy makers. By focusing on the specific training backgrounds of participants and allowing them to elaborate on when they began research collaboration, why they began collaborating, and how their training relates or does not relate to their preparation and development as collaborative researchers we gain a better understanding of what experiences are uniquely formative. It is those uniquely formative experiences in the development of collaborative researchers that should be emphasized in grant programs and policies designed to promote greater collaboration and, by extension, the U.S. research agenda.

The final organizational category recognizes that while quantitative analysis can articulate differences and similarities within and between groups, it is poorly equipped for developing an understanding of what these differences or similarities mean to the individuals involved. By examining how non-U.S. citizen and U.S. citizen faculty members understand their personal constraints and advantages related to collaborative activity, new insights can be gained not only into why these two groups engage in the collaborative activity that they do, but also into where this collaborative activity falls with respect to the individual's sense of the spheres of knowledge within his or her field of study. In other words, it is important to allow the individual participant to define his or her own understanding of what is local knowledge and what is cosmopolitan. Rather than impose an individually uncontextualized and subjective measure of the relative strength of ties participants have to scholars within their broad network of colleagues, participants were allowed to define for themselves what they consider to be their strong ties and loose ties. This enables the study to move beyond a spatially defined sense of

strong and weak ties, which, it can be argued, is increasingly irrelevant to those with means in a globally connected knowledge economy, and toward a user-defined sense of the relative strength of their ties that is driven by the frequency and redundancy of knowledge exchanged, rather than on where the information is coming from. This line of inquiry adds to our understanding of how social network theory in general and its strength of weak ties hypothesis in particular can explain collaboration within an increasingly heterogeneous population of researchers. For details on the specific questions that were asked under each of the four organizational categories, the full interview protocol can be found in Appendix 2.

Site and Sample

The research site for the qualitative interviews was a North Central Association of Colleges and Schools (NCA) accredited public research university located in the Mid-Western region of the United States. The institution serves as the flagship university for its state and has been classified by the Carnegie Foundation for the Advancement of Teaching as a Doctoral/Research University-Extensive. This classification is designated for those institutions that have a broad variety of baccalaureate programs and award at least 50 doctoral degrees in any given year across a minimum of 15 academic disciplines. In the 2008/2009 academic year, the institution granted 4,097 bachelor's degrees, 1,481 masters degrees, 263 research doctorate degrees, and another 503 doctorate professional-practice degrees within its thirteen schools. The university includes a medical school.

The university enrolls nearly 28,000 students on its main campuses and employs just over 2,400 faculty members. Of these faculty members, 77.5% are full-time and 22.5% are part-time, 58.7% are male and 41.3% are female, and 44.9% are tenured and 14.4% are tenure-track. There

are 707 assistant professors employed by the university and 570 associate professors. Citizenship data are not publically available for faculty members at the institution.

Of the nearly 28,000 students, just over 21,800 are undergraduate students and just under 6,200 are graduate students. The gender breakdown of the student population is approximately 49% male and 51% female. The majority of students (82.1%) are full-time, and just over 69% of the students hail from the state the institution is located in. Just over 1,900 international students are enrolled.

Mimicking the population studied using 2006 SDR data, the university participants in the qualitative portion of this study worked as full-time, tenure-track or tenured professors at the assistant or associate rank. All participants held positions within the SEH disciplines and all were within the first ten years of employment at the university. Participants were purposefully selected (Creswell, 2003; Maxwell, 2005; Merriam, 1998; Silverman, 2001) for inclusion in the study based on the criteria just articulated. Faculty profiles on departmental web sites were evaluated for suitability. Faculty members meeting the selection criteria were then contacted by email to see if they would be willing to participate in the study. The same email text was used to contact all participants and a description of the study was included in the body of the email. In-person interview appointments were arranged with interested participants. Interviews were conducted at a convenient time for the faculty members and, with the exception of two, were held in the participant's own office to maximize the convenience and facilitate their comfort and familiarity with the surroundings. One interview was held in the researcher's own office, and the other was held in a quiet corner of a coffee shop. Upon in-person confirmation of participants' background and eligibility for study participation, a written informed consent form was carefully

reviewed with each interviewee and signed prior to the start of the interview. A copy of the informed consent form was given to participants at that time (See Appendix 1).

In all, 20 university faculty members were purposefully selected for participation. This group comprised 10 male faculty members and 10 female faculty members. Within each gender group half of the respondents (5 in each gender group) met the study's definition of international faculty members and half met the study's definition of U.S. citizen faculty members. All non-U.S. citizens at the time of the study either held a U.S. permanent resident visa (Green Card) or a temporary U.S. resident visa (such as H-1B, F-1, J-1, TN, or O-1) status. To further protect the anonymity of the participants and ensure a safe environment for conversing, the same group of four broad disciplinary categories was used for identification purposes as for the SDR data. Five faculty members were from the social sciences, 5 were from the life sciences, 5 were from the physical sciences, and five were from the engineering fields.

As this study focuses on early-career faculty members, half of the participants were at the assistant professor rank at the time of the interviews and half were at the associate professor rank. Years on the job within each faculty rank varied so as to explore how career transition may or may not impact collaborative research behavior. The only characteristic not purposefully selected for this group was postdoctoral research history. Due to the exclusion of faculty members from the humanities in order to be in closer alignment with the SDR dataset, the prevalence of postdoctoral research experience was high, with three quarters of the group (15) having held a postdoctoral position between completion of their doctorates in the United States and the start of their faculty careers. All interviewees completed their Ph.D. within the United States, and those who completed a postdoctoral appointment also did this work in the United States.

Prior to beginning the core interviews, two pilot interviews were conducted (one with a domestic faculty member and one with an international faculty member) to test the interview protocol and allow for minor modifications prior to the commencement of the formal study. For the pilot interviews, the procedures and informed consent process were identical.

Method of Inquiry

Each interview session began with five to ten minutes of casual un-recorded conversation to relax the interviewee and to establish a friendly rapport. The formal part of each session began with a test of the recording equipment. Interviews were digitally recorded onto a laptop computer using an unobtrusive high-definition USB microphone. WAV files were generated and transferred to a password-protected external hard drive. Each interview file was labeled with a participant number in sequential order. Names of participants were not stored with the data nor used in subsequent transcriptions or written documents. In cases where a name was used, an alias was assigned. A separate paper document listing participant numbers and names has been kept in a locked file cabinet and stored separately from the interview data. No data or participant names were stored on the laptop computer.

The interviews lasted from 45 to 70 minutes each and focused on the four organizational topics articulated above. A semi-structured format was used to guide the interviews and ensure consistent coverage across participants. The interview protocol was divided according to the four organizational categories that have been articulated (see Appendix 2). The first question was designed to engage the respondent in a discussion regarding the types of collaboration he or she engages in when conducting research.

The second set of questions was designed to explore the operational aspects of collaboration. Key questions focused on what respondents felt they gain from their collaborative work; how those gains vary by type of collaboration; the professionally- and/or personally-driven nature of their collaborative activities; how the decision on when and who to collaborate with is made; how collaboration choices differ based on the desired project outcomes; how access to collaborators is gained; the process of establishing reciprocity; and the bidirectional or lack of bidirectional nature of collaborative activity. A complete interview protocol can be found in Appendix 2.

The next set of questions on the interview protocol delved into participants' perceptions of the relative and collective of impact of the training experiences faculty members had. In particular, participants were asked to describe how each of their experiences impacted their development as collaborative researchers. Participants were also asked about other experiences that contributed to their development as collaborative researchers, and about the nature of their first collaborative research project in order to gain an understanding of when research collaboration typically begins and how formative those experiences are. The final set of questions on the interview protocol addressed participants' perceptions of the advantages and disadvantages that they experienced by nature of their citizenship status with respect to the four types of collaborative activity being explored. Non-U.S. citizen faculty members were asked if they feel that their status facilitates or hinders their collaboration at the departmental, intra-institutional, inter-institutional, and/or international levels. Their reasons for feeling this way were also explored, as well as how their status affects their choice of the type of collaborative activity to engage in. Citizen participants were asked the same set of questions, but from their perspective as U.S. citizens. The final question on the interview protocol directed the participants

to place themselves in the shoes of their counterparts with a different citizenship status and to elaborate on how they would imagine their collaborative work would be facilitated or constrained.

Upon the conclusion of each interview the WAV file was transferred to an external hard drive from the computer and password protected before the process of transcription began. For transcription purposes, the WAV files were played back using iTunes. This enabled immediate and seamless pausing and restarting, as well as time coding to enable me to quickly re-locate and listen to sections of interest within the interviews upon completion of the transcriptions. Full transcriptions were written in Microsoft Word for all 20 interviews and in addition to time coding each section of the interviews, each line was numbered to facilitate the process of data analysis. Interviews were conducted in blocks of 4 participants (two U.S. citizens and two non-U.S. citizens in each block). Each block was fully transcribed and evaluated for emergent themes before the next block of participant interviews began. This iterative process enabled me to adapt the main questions and prodding questions for precision and clarity, and enabled me to pursue emerging themes and differences in greater depth in future interviews. This process also provided me with an opportunity to follow up with interviewees to clarify their statements and ensure that I had captured their meaning prior to going too far ahead with the study.

Several steps were taken in the analysis of the transcription data. First of all, a constant comparative approach was applied both within a particular transcription and between transcriptions (Merriam, 1998, p. 159). This approach enabled me to flesh out rough categories for the data to guide my efforts over the course of future interviews, draw preliminary conclusions in terms of data trends and themes, and to evaluate the level of internal reliability of

what the study participants were saying to enable me to follow up with data inconsistencies or areas that were unclear.

In order to apply the constant comparative method, I began coding my data into tentative categories. I did this at the end of each group of four interviews after the transcriptions were complete. This involved reading each transcription several times, while coding and re-coding emergent categories. Changes had to be made frequently in the category labels as my understanding of the categories shifted and became more complete. For each interview, a bulleted summary of emergent or tentative categories was developed. This enabled me to efficiently identify broader themes within a particular respondent's data and, over the course of acquiring additional data from subsequent interviews, identify emergent themes and unique features that spanned across informants.

By number-coding each participant's set of categories (a different number for each participant, rather than for each category), I was able to reorganize the data across subjects to more fully describe the categories themselves, and subsequently the themes that these categories fell into. The number coding also enabled me to obtain an understanding of how individual differences are reflected in each of the categories, develop a more complete conception of each category by exploring the different facets that each of my study participants brought to the table, and, as the themes began to emerge, enabled me to explore how each participant might relate to a particular theme. In other words, I was able to examine whether a participant might see a theme as more tangentially or directly related to their own experiences. It should be noted that my language related to category building differs somewhat from that of Merriam (1998). While Merriam refers to the creation of categories and subcategories (or properties) (Merriam, 1998,

pp. 179-180), I have been describing the process of identifying categories and articulating their multiple facets. I believe, however, that Merriam and I are referring to the same process.

Verification and Trustworthiness

Two methods were used to verify and ensure the trustworthiness of the data. While David Silverman (2001, p. 236) rightly points out that there is no reason to assume that interview respondents enjoy privileged status with regard to commenting on their own actions or responses to a survey, I do believe that in the present circumstances accurate transcription of interviews and the correct interpretation of *intended* comments is of paramount importance and warrants an attempt at respondent validation. Especially when working with a non-native English-speaking population, having respondents read what they have said is important to determining the intended meaning in their remarks. Non-native verbal and reading skills often vary considerably and this study focuses on meaning, interpretation, and perception, rather than upon the analysis of speech or a particular choice of words. Silverman indicates that respondent validation is less a confirmation of the absence of interview bias or a determination of the absolute validity of what has been recorded to date, and more an additional set of data to guide the interpretation of results. That additional data does seem to be important for this study.

Given the generosity with which respondents had already given their time to participate in the interviews, I did not want to burden them with full transcriptions of the interviews. Instead, the full write-up of the interview results, quotes, and analysis were shared will all study participants. While I was unable to verify that each participant reviewed these materials, nearly half (8) confirmed that the write-up accurately reflected what they had told me during the

interviews. This was also an important step in ensuring that each participant's anonymity had been maintained.

The other method that I used to arrive at some sense of the data's trustworthiness was the constant comparative method. After the initial interviews and their transcriptions, I was able to generate a set of categories and tentative themes for those categories based on the first four participants' responses to my interview questions. These categories and themes were evaluated to look for internal inconsistencies and conflicts. As additional respondents were interviewed and their responses coded and analyzed, the categories and themes were continually revised and refined to ensure that they accurately encapsulated the perspectives of the participants.

Ethical Considerations

Prior to beginning interviews, the interview protocol and detailed description of the study were submitted to the university's Internal Review Board (IRB or Human Subjects Committee) for review and approval. A complete inventory of the research activities was given, the project purpose was articulated, a description of the prospective subject characteristics and the selection process was given, and an abstract of the procedures for the study was articulated. Upon approval from the IRB, participants were asked to read and sign an informed consent form prior to participating in the study. At the time of signing the consent form it was emphasized that all information would be kept confidential and secure, and that the respondent could stop the interview at any time. To protect participants, all names in this study have changed. Furthermore, all recordings, transcriptions, and notes were placed on a password-protected external hard drive to ensure their security. Backup files were also password-protected.

Study Limitations

Naturally there are several limitations with this study. First of all, this portion of the study has limited generalizability due to the fact that only 20 participants were interviewed (Creswell, 2003). Participant numbers were insufficient to make any broader conclusions on collaborative activity by gender, field of study, or immigration status. The prevalence of the postdoctoral research position among those interviewed also meant that those without such experience (5 respondents) were not as well represented within the sample population. An additional set of limitations relates to the scope and timeframe of the study. While member checks and constant comparative methods were employed, observation of the participants in a collaborative research setting was not feasible. Furthermore, multiple interviews were not done with individuals, peer examination of my findings was not be sought, and my results were not be triangulated by other investigators and/or multiple data sources such as document analysis or observation notes.

A final limitation of my study relates to the transcriptions themselves. Since I was unable to have someone independently verify the accuracy of my full transcriptions, I was not able to assert with absolute confidence that every line of every transcription was perfectly accurate, especially given that nearly half of the respondents were non-native speakers of English and had varying levels of accent to their English. It was hoped, however, that by providing each respondent with a summary of their comments, the key features and themes of their remarks remained intact.

Researcher Positionality

Just as the subject of inquiry itself, qualitative research reflects a collaborative process in which the interview participants and interviewer negotiate meaning (Merriam, 1998, p. 6).

Therefore an understanding of the researcher's positionality is important to the interpretation and understanding of the study's results and the conclusions that are drawn from those results. As a doctoral student and practicing professional in higher education, I bring a motivation and commitment to my research that is fueled by my conviction that such research is critical to developing informed policy, appropriately allocating scarce resources, and creating new programs and services within the context of higher education. I am also convinced that higher education can always be enhanced and that programs should be developed, maintained, adapted, and improved in a deliberate fashion.

I have spent a significant portion of my life living, studying, working, and traveling abroad, and have spent the past fourteen years working in administration within the public higher education context. Most of my administrative experience at the university level has been directly in the international arena. As such, I have had the opportunity to work with domestic and international faculty, students, and staff on program development, grant and proposal development, curricular reform, scholarly exchange, immigration, and educational development initiatives. Collaboration has deep meaning to me personally and professionally as I rarely go through a week that does not involve connecting with a member of my extended network of colleagues at the local, national, and/or international level. My work has spanned the disciplines and has also involved the building of university consortia that are inclusive of U.S. university partners, as well as international university partners. Furthermore, in my work with doctoral students applying for nationally competitive grants, including those pursuing degrees in the SEH disciplines, I have been in the role of mentoring students on the importance of getting letters of institutional affiliation from institutions abroad. For some students this is something that they

have learned elsewhere. For others, however, I feel that I am playing a key role in their scholarly development and participation.

Taken together, my educational training, life experiences, and professional background have given me a first-hand opportunity to witness the opportunities and challenges of collaboration at the institutional, inter-institutional, and international levels. For my own work, I am hugely reliant upon the affiliations that my university has with institutions abroad. These linkages enable me to bring international faculty, administrators, and students to campus, and provide me with a link for sending our own faculty, students, and administrators abroad. Furthermore, in my grant- and immigration-related work, I have seen how federal funding and immigration agencies have increased their emphasis on multi-institutional collaborations. For example, funding agencies often require that formal partnerships be established between institutions prior to submitting grant proposals. Furthermore, for immigration petitions evaluating a scholar's academic credentials and scholarly productivity, U.S. Citizenship and Immigration Services places specific emphasis on letters of recommendation from abroad, publications in journals of international repute, and global research impact as evidenced by patents registered in the United States and abroad. In recent years, I have worked with the Schools of Education, Engineering, Architecture, Medicine, Pharmacy, Journalism, Law, Business, Social Welfare, and the College of Liberal Arts and Sciences on creating collaborative partnerships with universities, individuals, and laboratories from around the world to enhance their educational and research missions. These partnerships have emerged from direct collegial relationships, through networks of researchers working in related areas, out of the need for particular equipment and/or expertise, and on account of the directives of funding agencies. Anecdotally, I have also seen more involvement in the university's international activities and

collaborations among international faculty and domestic faculty who have spent substantial time living, studying, and working abroad.

Due to these experiences and observations, I am aware of several assumptions that I bring to this study. These include a belief that all universities are collaborative at the local, regional, national, and global levels; collaboration is good and should be encouraged; faculty members knowingly participate in collaborative activity and recognize it as such; faculty members who collaborate gain access to information and resources outside of their immediate environment that can be useful to their research objectives; there is institutional support and encouragement for collaborative activity; my personal work facilitating international collaborations among faculty, students, and administrators is valuable and worthwhile; funding agencies are effectively conveying their preference for proposals that involve collaborative activity and this is resulting in behavioral changes among principal investigators and their research teams; the benefits of collaboration are felt; people do not become collaborative or skilled at collaboration overnight, but gain this experience over the course of their studies and careers; barriers that researchers encounter in their collaborative activities are surmountable; non-citizen faculty members are more likely to seek out international collaborations than their domestic colleagues; and domestic faculty are more likely to collaborate internationally if they have had substantial international experience.

Several secondary goals, which supplement the primary goals that I have already articulated, have emerged on account of my personal and professional experiences and the assumptions that I have just articulated. While these goals will not all be achieved with this project, it is hoped that this study will enable me to move closer to their fulfillment. These secondary goals include: to hear first-hand from faculty members about why they collaborate and

how the different people they collaborate with help them to achieve their research objectives; to develop institutional approaches that can enhance our ability to train tomorrow's researchers to be effective collaborators; to establish mechanisms to encourage and support faculty collaboration at the institutional, national, and international levels; and to collect a strong set of faculty-contributed and experientially-based reasons for collaboration beyond the immediate laboratory environment that can be used to raise awareness and generate momentum for collaborative initiatives.

I approach this study with several advantages due to my personal and professional experience. These include: the personal empathy (that comes from substantial administrative experience within the university context and with international collaborations) to hear stories, understand their meaning, and draw these stories out more completely with appropriate and informed follow-up questions; my work in an office that plays a public and largely positive role on campus for its internationalization initiatives and faculty support programs; and a deep understanding of and personal experience with the federal grant environment in which the faculty members live and rely upon to support their research.

I also come to this study facing several disadvantages as an investigator. This includes a clear predisposition to focus on the problems and institutional shortcomings related to collaboration. Furthermore, my own experiences and assumptions may have consciously or unconsciously biased my questions, especially in the context of more unstructured interviews where the questions evolve and emerge as the conversations continue. In addition, faculty members may not have been entirely candid with me, knowing that I work for an institution of higher education, have a professional and scholarly stake in higher education, and may know some of their colleagues. Finally, with an overarching goal to enhance collaboration and develop

programs and policies that support this activity, I may be reluctant to accept that additional collaboration is not needed, not warranted, or not wanted. As I proceeded with this research I made every effort to account for my experience, connection to the population that I was researching, and the unique set of parameters that I necessarily bring to my work.

CHAPTER 4: RESULTS OF THE QUANTITATIVE ANALYSES

Chapter 4 describes the results of the quantitative stage of the study. After a preliminary overview of the study population characteristics, descriptive and inferential results are reported in order of the two primary quantitative research questions articulated in Chapter 1. These questions include:

- *What forms of collaborative research activity are most representative of early-career faculty researchers working in the U.S.?*
- *What factors predict early-career faculty researchers' participation in collaborative activities, with particular attention to the unique effects of field of study, institutional type, postdoctoral research experience, and/or international faculty status?*

Study Population Overview and Background Statistics

As reported in Chapter 3, the weighted number of 2006 SDR respondents eligible for inclusion in the study was 47,849. Table 4.1 shows how this population breaks down by citizenship, gender, tenure status, and postdoctoral research history as these descriptive variables were of particular focus in the analyses that followed.

Table 4.1

Study Population Overview

		Frequency	*Percent*
Citizenship	U.S.	38,154	79.70%
	International	9,695	20.30%
Gender	Female	18,982	39.70%
	Male	28,866	60.30%
Tenure Status	Yes	11,735	24.50%
	No	36,114	75.50%
Postdoc	Yes	17,797	37.20%
	No	30,051	62.80%

Nearly 80% percent of respondents held U.S. citizenship at the time of the survey, while just over 20% had either an immigrant or non-immigrant status as international faculty members. The gender distribution for the entire population (60% men to 40% women) was similar to that of the U.S. citizen population (58% to 42%), while the international population had a higher percentage of men represented (69%) as compared to women (31%). The gender distribution within the two main study populations is reported in Table 4.2.

Table 4.2

Gender Distribution by Citizenship Status

		Frequency	*Percent*
U.S. Citizenship	Female	16,002	41.94%
	Male	22,151	58.06%
International	Female	2,980	30.74%
	Male	6,715	69.26%

Tenure status was another descriptive variable that was examined for the study. Just under 76% of the study-eligible respondents were in tenure-track positions but untenured at the time of completing the 2006 SDR (See Table 4.1). With regard to the prevalence of the postdoctoral research position in respondents' employment history, the majority of faculty respondents (63%) had not held a postdoctoral research position prior to beginning their faculty careers (Table 4.1). Over 80% of survey respondents had held only 1 postdoctoral appointment.

For those respondents who completed a postdoctoral research assignment prior to commencing their faculty careers, the overwhelming majority (85%) had completed postdoctoral work within the higher education sector. Government postdocs were the second highest sector of employment for this group at 8%, followed closely by postdocs in the private sector (6). Table

4.3 shows this sector distribution, as well as the relative percentages within each sector held across both citizenship types and genders.

Table 4.3

Postdoctoral Employment Sector by Citizenship and Gender

			Frequency	*Percent*	*Case Total*
Education	**Citizenship**	U.S.	11,960	78.74%	15,190 (85.30%)
		International	3,230	21.26%	
	Gender	Female	5,691	37.47%	
		Male	9,499	62.53%	
Company/Org	**Citizenship**	U.S.	783	77.99%	1,004 (5.60%)
		International	221	22.01%	
	Gender	Female	377	37.58%	
		Male	626	62.42%	
Government	**Citizenship**	U.S.	1,277	86.17%	1,482 (8.30%)
		International	205	13.83%	
	Gender	Female	466	31.44%	
		Male	1,016	68.56%	

Academic field was also examined for the SDR population under study. Those working in the social sciences represented the largest field subpopulation, with 36% of respondents fitting into this category. Overall, more women were in the social sciences field (8,711), than any other field category. Among those in the social sciences, 49% of the population consisted of men. Table 4.4 shows the gender and citizenship distribution for each field of study under analysis, as well as the relative overall percentages of respondents in each broad disciplinary category.

After social sciences, the next most frequent field among all respondents was the life sciences (28%), followed by physical sciences (20%), and engineering (17%). As reflected in the frequency data reported in Table 4.4, this disciplinary ordering was maintained for both men and women, as well as for U.S. citizens.

Table 4.4

Field of Study by Citizenship and Gender

			Frequency	*Percent*	*Case Total*
Social Sciences	**Citizenship**	U.S.	14,655	85.48%	17,144 (35.80%)
		International	2,489	14.52%	
	Gender	Female	8,711	50.81%	
		Male	8,433	49.19%	
Life Sciences	**Citizenship**	U.S.	11,508	87.08%	13,216 (27.60%)
		International	1,708	12.92%	
	Gender	Female	5,800	43.89%	
		Male	7,416	56.11%	
Physical Sciences	**Citizenship**	U.S.	6,975	74.33%	9,384 (19.60%)
		International	2,409	25.67%	
	Gender	Female	2,689	28.66%	
		Male	6,695	71.34%	
Engineering	**Citizenship**	U.S.	5,015	61.88%	8,105 (16.90%)
		International	3,090	38.12%	
	Gender	Female	1,782	21.99%	
		Male	6,322	78.01%	

International faculty were the sole exception to this ordering with the largest group indicating engineering as their field (3,090), followed by social sciences (2,489), physical sciences (2,409), and then life sciences (1,708). These data comport well with the findings of the National Science Board, which indicate a disproportionate and rapidly growing number of graduates with doctorates in engineering are temporary U.S. residents (Lee, 2001; NSB, 2008).

The prevalence of the social sciences may be one reason that the overall postdoctoral numbers for the selected respondents from the dataset were relatively low at 37%. Postdoctoral research opportunities are known to be less common in the social sciences (Davis, 2005; Hoffer, Grigorian, & Hedberg, 2008; National Postdoctoral Association, 2009). Table 4.5 shows the prevalence of the postdoctoral research experience across the study population by field of study.

Table 4.5

Prevalence of the Postdoctoral Experience by Field of Study.

Postdoctoral Experience	Percent Indicating "yes"				
	All	*U.S.*	*International*	*Male*	*Female*
All Fields	37.19%	37.06%	37.71%	38.94%	34.55%
Physical Sciences	52.15%	52.65%	50.68%	53.99%	47.56%
Life Sciences	51.77%	51.16%	55.85%	58.81%	42.79%
Engineering	29.21%	27.80%	31.18%	29.26%	29.05%
Social Sciences	21.55%	21.67%	20.81%	16.78%	26.17%

Across both citizenship statuses and genders, the social sciences had the lowest prevalence of postdocs. Table 4.5 also indicates a high level of within-field consistency across gender and citizenship with respect to the prevalence of the postdoctoral research experience. On average, 1out of every 2 respondents in the physical and life sciences had held a postdoctoral appointment prior to beginning their faculty careers. Comparatively, just around a quarter of respondents in the social sciences reported a postdoctoral research history, while those in engineering averaged around 30%. This is consistent with national data (Hoffer, Grigorian, & Hedberg, 2008).

Finally, weighted respondent data was examined to determine the distribution of respondents by Carnegie classification. Table 4.6 provides a complete overview of the study population by Carnegie classification. The majority of respondents worked at Research I universities (32.73%). This was followed by Comprehensive I (28.32%), Research II (7.87%), Doctorate II (7.21%), Liberal Arts II (6.74%), Liberal Arts I (5.43%), Doctorate I (5.16%), Medical (2.91%), Comprehensive II (1.95%), and Other (1.67%). Male faculty members outnumbered female faculty members for every institutional type except at Liberal Arts I institutions. International faculty members comprised the highest percentage of faculty members at Research II institutions (26.64%), followed by Research I institutions (25.77%) and Doctorate Granting II institutions (23.96%).

Table 4.6

Carnegie Classification by Citizenship and Gender

			Frequency	*Percent*	*Case Total*
Research I	**Citizenship**	U.S.	11,218	74.23%	
		International	3,895	25.77%	15,113
	Gender	Female	5,581	36.93%	32.73%
		Male	9,532	63.07%	
Research II	**Citizenship**	U.S.	2,666	73.36%	
		International	968	26.64%	3,634
	Gender	Female	1,132	31.15%	7.87%
		Male	2,502	68.85%	
Doctorate Granting I	**Citizenship**	U.S.	1,970	82.70%	
		International	412	17.30%	2,382
	Gender	Female	1,028	43.16%	5.16%
		Male	1,355	56.88%	
Doctorate Granting II	**Citizenship**	U.S.	2,532	76.04%	
		International	798	23.96%	3,330
	Gender	Female	1,067	32.04%	7.21%
		Male	2,264	67.99%	
Comprehensive I	**Citizenship**	U.S.	10,744	82.17%	
		International	2,331	17.83%	13,075
	Gender	Female	5,729	43.82%	28.32%
		Male	7,347	56.19%	
Comprehensive II	**Citizenship**	U.S.	831	92.13%	
		International	71	7.87%	902
	Gender	Female	365	40.47%	1.95%
		Male	537	59.53%	
Liberal Arts I	**Citizenship**	U.S.	2,288	91.26%	
		International	219	8.74%	2,507
	Gender	Female	1,302	51.93%	5.43%
		Male	1,206	48.11%	
Liberal Arts II	**Citizenship**	U.S.	2,735	87.89%	
		International	377	12.11%	3,112
	Gender	Female	1,351	43.41%	6.74%
		Male	1,761	56.59%	

Table 4.6 (Continued)

Carnegie Classification by Citizenship and Gender

			Frequency	*Percent*	*Case Total*
Medical	**Citizenship**	U.S.	1,159	86.17%	
		International	186	13.83%	1,345
	Gender	Female	568	42.23%	2.91%
		Male	777	57.77%	
Other	**Citizenship**	U.S.	718	93.37%	
		International	51	6.63%	769
	Gender	Female	158	20.55%	1.67%
		Male	611	79.45%	

Forms of Research Collaboration

The first research question addressed in the quantitative stage of this study was, "What forms of collaborative research activity are more representative of early-career faculty researchers working in the U.S.?" As shown in Table 4.7, the most common type of collaboration that faculty member respondents reported engaging in on the 2006 SDR was intra-institutional collaboration beyond the team level. Of the 47,849 weighted respondents, 35,452 (74%) reported collaborating with colleagues at the same university when conducting their research. This was followed by team-level collaboration (63%), inter-institutional collaboration (60%), and international collaboration (26%).

Looking across citizenship and gender groups, Table 4.8 shows that intra-institutional collaboration was the highest form of collaboration reported by all subpopulations. For men, women, and U.S. citizens, team collaboration was the second highest form of reported collaboration. The only subpopulation that proved different was the international faculty respondents, who indicated engagement in inter-institutional collaborations (66%) more frequently than team collaboration (61%). This was the opposite for all other subgroups studied.

Table 4.7

Percent of Qualifying 2006 SDR Respondents Engaged in Different Types of Collaborative Work

Collaboration Type	*Frequency*	*Percent*
Work within a Team	30,256	63.2%
Work with Others at Same Institution but Outside Team	35,452	74.1%
Work with Others at Different Institutions	28,995	60.6%
Work with Others Abroad	12,626	26.4%

Across the board, international collaboration was cited with the least frequency with roughly 22% of women, 25% of U.S. citizens, and 29% of men reporting this type of collaborative activity (Table 4.8). Once again, however, international faculty members stood out from the other subpopulations, with 32% reporting collaboration at the international level.

Table 4.8

Collaboration Patterns by Different Subpopulations

Collaboration Patterns	Percent Indicating "YES"				
	All	*U.S.*	*International*	*Female*	*Male*
Team	63.20%	63.76%	61.16%	62.02%	64.03%
Intra-Institutional	74.10%	75.13%	70.02%	71.83%	75.58%
Inter-Institutional	60.60%	59.30%	65.70%	57.54%	62.61%
International	26.40%	24.86%	32.41%	21.98%	29.28%

While the overall collaboration statistics show a high level of consistency across groups, with intra-institutional collaboration cited the most often and international collaboration cited the least often, the apparent differences at the team and inter-institutional levels for international faculty, as well as the slightly lower levels of collaboration for women across the board

reinforced the importance exploring the predictive capabilities of both citizenship status and gender in the regression analyses.

Predictive Factors for Collaborative Research Activities

Reliability Tests for the Dependent Variables

To answer the last quantitative research question, "What factors predict early-career faculty researchers' participation in collaborative activities," four separate logistic regressions were conducted corresponding with each of the four forms of collaboration under study. Before the regressions, initial reliability tests were run in SPSS to evaluate the independence of the dependent variables and to determine if some of the dependent variables should be combined into single variables for purposes of analysis. Using a threshold Cronbach's Alpha score of .75, it was determined that the four collaboration measures should be kept as separate dependent variables representing separate dimensions of collaboration. The overall Cronbach's Alpha score for the four variables was .514 (Table 4.10) and as Table 4.9 shows, the dependent variables' level of inter-item correlation was relatively low.

Table 4.9

Inter-Item Correlation Matrix for the Dependent Variables

	Team	*Organization*	*U.S.*	*International*
Team	1	0.192***	0.207***	0.105***
Intra-Institutional	0.192	1	0.242***	0.148***
Inter-Institutional	0.207	0.242	1	0.360***
International	0.105	0.148	0.36	1

* P < .05, ** P < .005, *** P< .001

Removing the dependent variables individually did not improve the reliability scores of the remaining dependent variables. This was a further indication that the dependent variables

could not be effectively combined since the removal of individual dependent variables did not improve the reliability statistics for the remaining dependent variables. Table 4.10 shows the change in reliability statistics by a step-wise removal of the individual dependent variables from the equation.

Table 4.10

Reliability Statistics for Dependent Variables

	Cronbach's Alpha
Complete Model	0.514
Without Team	0.500
Without Intra-Institutional	0.462
Without Inter-Institutional	0.342

Four regressions were initially run to explore for possible interaction effects between respondents' postdoctoral research history and their citizenship. The rationale for examining this interaction effect stems from the frequency data reported in the previous section. The descriptive statistics indicated that the collaboration patterns differed by both postdoctoral research experience and citizenship status. The aim of running these initial regressions was to clarify if the effects of postdoctoral experiences on collaboration patterns differ by citizenship status and if the effects of citizenship on collaboration patterns differ by gender.

When each of the four regressions were run with the postdoctoral research history / citizenship interaction effect included, the interaction variable did not prove significant for any of the regression models. Because the product term must be significant for the interaction effect to be interpretable (Center for Family and Demographic Research, 2010), the interaction variable was removed and the postdoctoral experience and citizenship variables were added back in as separate independent variables. The interaction effects of gender and citizenship, as well as gender and postdoctoral history were also examined without statistically significant results.

The final four regressions were run without any interaction effects included given that there was no statistical evidence to support the existence of interactions between the independent variables included in the analysis. Age, time since degree, gender, tenure status, field, citizenship, postdoctoral research history, and institutional Carnegie classification were the independent variables included in the regression model.

For each of the four regressions, Likelihood Ratio Tests and Hosmer & Lemeshow Goodness-of-Fit Tests were run. As Tables 4.12, 4.13, and 4.14 show in detail, the Hosmer and Lemeshow statistics for the intra-institutional, inter-institutional, and international collaboration regressions had probabilities greater than .05, indicating that the null hypothesis of a good model was tenable for each (Peng, Lee, & Ingersoll, 2002). Hosmer and Lemeshow statistics for the team-level collaboration (Table 4.11), however, had a probability less than .05, indicating that the null hypothesis of a good model fit may not be tenable. The Likelihood Ratio Tests for each of the four regressions, however, were significant at the .001 level, so the four models with the independent variables of the study included were more effective than the null models for each form of collaboration (Peng, Lee, & Ingersoll, 2002).

Team-Level Collaboration

Table 4.11 shows the results of the logistic regression that was conducted with team-level collaboration serving as the dependent variable. As can be seen from the results reported in Table 4.11, age, years since completing the doctoral degree, field, citizenship, and institutional Carnegie classification all proved significant predictors of team-level collaboration. For ease of interpretation (Center for Family and Demographic Research, 2006), the odds ratios (Exp(B)) were converted into the percent change in the odds of the dependent variable having a value of 1

(a positive outcome for team collaboration). This was done by subtracting the odds ratio from 1 and multiplying by 100 (Center for Family and Demographic Research, 2006). The far right column in Table 4.11 shows the percent change in odds for the significant independent variables in the regression equation.

As Table 4.11 shows, as age increases by one year for the respondent population the odds of collaborating at the team level increase by 1.9%. For each additional year added since completing the doctoral degree, the odds of collaborating at the team level increased by 9.3%. Field also proved significant. Faculty in the life sciences had greater odds of participating in team-level collaboration than their peers in the social sciences. Similarly, the odds of engineers collaborating at the team level increased by 212.7% compared to their colleagues in the social sciences, and physical scientists had a 88.4% increase in their odds of collaborating at the team level. Respondents with international citizenship status had a 21.5% decrease in their odds of collaborating at the team level as compared to their U.S. citizen peers. Respondents who had held a postdoctoral research position prior to beginning their faculty careers had the same odds statistically of collaborating at the team level as compared to those who had not held a postdoctoral position.

The inclusion of institutional type in the regression model for team collaboration indicated that Carnegie classification was enormously important as a predictor. Faculty members working at a medical school or center had the highest odds of collaborating at the team level with odds at 937.2% greater as compared to all other institutional types combined. This was followed by those at Research I institutions (290.8%), Doctorate Granting II institutions (206.7%), Research II institutions (157.4%), Doctorate Granting I institutions (152.7%), and finally Comprehensive I institutions (104.6%).

Table 4.11

Logistic Regression Results for Team-Level Collaboration

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*% Change*
Age	.019	.008	6.395	1	0.011	1.019*	1.9
DegreeYrs	.089	.022	16.160	1	0.000	1.093***	9.3
Gender (male)	-.022	.093	.057	1	0.812	.978	
Tenure (tenured)	.088	.123	.507	1	0.477	1.092	
Social Sciences (reference)			103.013	3			
Life Sciences	.993	.123	65.419	1	0.000	2.699***	169.9
Engineering	1.140	.140	66.676	1	0.000	3.127***	212.7
Physical Sciences	.633	.129	24.133	1	0.000	1.884***	88.4
International (non-citizen)	-.243	.118	4.255	1	0.039	.785*	21.5
Postdoc (had postdoc)	.157	.107	2.152	1	0.142	1.170	
Research I	1.363	.355	14.736	1	0.000	3.908***	290.8
Research II	.945	.380	6.195	1	0.013	2.574*	157.4
Doctorate Granting I	.927	.395	5.496	1	0.019	2.527*	152.7
Doctorate Granting II	1.121	.384	8.522	1	0.004	3.067**	206.7
Comprehensive I	.716	.353	4.107	1	0.043	2.046*	104.6
Comprehensive II	.450	.470	.915	1	0.339	1.568	
Liberal Arts I	.289	.389	.553	1	0.457	1.336	
Liberal Arts II	.733	.384	3.648	1	0.056	2.080	
Medical School / Center	2.339	.535	19.085	1	0.000	10.372***	937.2
Constant	-2.311	.456	25.651	1	0.000	.099	90.1
Omnibus Tests of Model Coefficients			□²	*df*	*p*		
Step			282.374	18	<.0001***		
Block			282.374	18	<.0001***		
Model			282.374	18	<.0001***		
Goodness-of-Fit Test							
Hosmer & Lemeshow			19.273	8	.013*		

*P < .05, ** P < .005, *** P< .001

Note: Cox & Snell R^2 = .114. Nagelkerke R^2= .155. -2 Log likelihood = 2822.202

Intra-Institutional Collaboration

The results of the logistic regression performed for intra-institutional collaboration can be found in Table 4.12. As the table shows, the predictive factors for intra- institutional collaboration were quite different from those predicting team-level collaboration.

Table 4.12

Logistic Regression Results for Intra-Institutional Collaboration

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*% Change*
Age	.002	.008	.042	1	0.837	1.002	
DegreeYrs	.028	.023	1.497	1	0.221	1.029	
Gender (male)	.189	.098	3.764	1	0.052	1.209	
Tenure (tenured)	.179	.131	1.869	1	0.172	1.196	
Social Sciences (reference)			26.204	3			
Life Sciences	.421	.131	10.365	1	0.001	1.524***	52.4
Engineering	.431	.147	8.580	1	0.003	1.539**	53.9
Physical Sciences	-.190	.133	2.053	1	0.152	.827	
International (non-citizen)	-.225	.121	3.475	1	0.062	.798	
Postdoc (had postdoc)	.017	.112	.023	1	0.880	1.017	
Research I	.300	.375	.639	1	0.424	1.350	
Research II	.316	.405	.610	1	0.435	1.372	
Doctorate Granting I	-.157	.413	.144	1	0.704	.855	
Doctorate Granting II	-.023	.401	.003	1	0.953	.977	
Comprehensive I	.178	.374	.225	1	0.635	1.194	
Comprehensive II	.012	.497	.001	1	0.980	1.012	
Liberal Arts I	.307	.415	.548	1	0.459	1.360	
Liberal Arts II	.036	.404	.008	1	0.930	1.036	
Medical School / Center	.862	.516	2.791	1	0.095	2.368	
Constant	.345	.476	.524	1	0.469	1.412	
Omnibus Tests of Model Coefficients			χ^2	*df*	*p*		
Step			62.453	18	<.0001***		
Block			62.453	18	<.0001***		
Model			62.453	18	<.0001***		
Goodness-of-Fit Test							
Hosmer & Lemeshow			9.713	8	.286		

* P < .05, ** P < .005, *** P< .001

Note: Cox & Snell R^2 = .026. Nagelkerke R^2= .038. -2 Log likelihood = 2648.730

While field was still a significant factor (with the exception of physical sciences), age, years since earning the doctorate, citizenship status, and institutional type were no longer significant predictors. This may be due to the already high levels of collaboration at this level for all groups studied (74% overall). Gender and citizenship status were both close as significant predictors,

but neither variable quite reached the significance threshold of .05 (.052 for gender and .062 for citizenship).

The percent change in the odds ratios was also calculated for the significant factors predicting intra-institutional collaboration. These results are reported in the far right column in Table 4.12. The percent change in odds indicate that faculty members in the life sciences had a 52.4% increase in the odds of collaborating at the intra-institutional level as compared to their peers in the social sciences. Engineers had a 53.9% increase in the odds of collaborating at the intra-institutional level as compared to the social scientists surveyed.

Inter-Institutional Collaboration

The next regression model evaluated the factors that predict collaboration between institutions in the United States. These results are reported in Table 4.13.

For the inter-institutional variable, only institutional type proved to be a significant predictor. Faculty members working at Research I institutions had higher odds of collaborating with colleagues at other U.S. institutions (211.3% higher) than their peers at other institutions. This was followed by those at Research II institutions (190.6%) and those at Doctorate Granting II institutions (159.5%). None of the other independent variables were significant predictors of inter-institutional collaboration.

Table 4.13

Logistic Regression Results for Inter-Institutional Collaboration

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*% Change*
Age	-.007	.007	.882	1	0.348	.993	
DegreeYrs	.014	.021	.425	1	0.514	1.014	
Gender (male)	.122	.091	1.819	1	0.177	1.130	
Tenure (tenured)	.090	.118	.579	1	0.447	1.094	
Social Sciences (reference)			5.577	3			
Life Sciences	-.017	.118	.022	1	0.883	.983	
Engineering	.103	.135	.581	1	0.446	1.108	
Physical Sciences	-.234	.128	3.373	1	0.066	.791	
International (non-citizen)	.184	.118	2.435	1	0.119	1.202	
Postdoc (had postdoc)	.028	.104	.074	1	0.786	1.029	
Research I	1.136	.343	10.956	1	0.001	3.113***	211.3
Research II	1.067	.372	8.221	1	0.004	2.906**	190.6
Doctorate Granting I	.531	.381	1.948	1	0.163	1.701	
Doctorate Granting II	.954	.372	6.587	1	0.010	2.595*	159.5
Comprehensive I	.159	.341	.219	1	0.640	1.173	
Comprehensive II	-.376	.463	.660	1	0.417	.686	
Liberal Arts I	.310	.376	.683	1	0.409	1.364	
Liberal Arts II	-.198	.371	.284	1	0.594	.821	
Medical School / Center	.809	.425	3.630	1	0.057	2.246	
Constant	-.070	.435	.026	1	0.872	.932	
Omnibus Tests of Model Coefficients			χ^2	*df*	*p*		
Step			160.499	18	<.0001***		
Block			160.499	18	<.0001***		
Model			160.499	18	<.0001***		
Goodness-of-Fit Test							
Hosmer & Lemeshow			3.032	8	.932		

*P < .05, ** P < .005, *** P< .001

Note: Cox & Snell R^2 = .066. Nagelkerke R^2= .090. -2 Log likelihood = 2972.471

International Collaboration

The final regression that was conducted examined international collaboration. Table 4.14 shows these results. For the first time tenure status proved a significant factor with tenured faculty members having increased odds of collaborating internationally than their untenured

colleagues by 33.6%. International faculty members also had 57.2% higher odds of collaborating at the international level than their U.S. citizen colleagues.

Among the institutional classifications, faculty members from Comprehensive I institutions (57%) and faculty members from Liberal Arts II institutions (60.2%) were both less likely to collaborate at the international level as compared to their peers at other institutional types.

Table 4.14

Logistic Regression Results for International Collaboration

Variables in the Equation	*B*	*S.E.*	*Wald*	*df*	*Sig.*	*Exp(B)*	*% Change*
Age	.007	.008	.609	1	0.435	1.007	
DegreeYrs	.016	.024	.432	1	0.511	1.016	
Gender (male)	.196	.101	3.781	1	0.052	1.216	
Tenure (tenured)	.290	.128	5.121	1	0.024	1.336*	33.6
Social Sciences (reference)			3.921	3			
Life Sciences	-.250	.132	3.608	1	0.057	.779	
Engineering	-.170	.143	1.406	1	0.236	.844	
Physical Sciences	-.108	.145	.559	1	0.455	.897	
International (non-citizen)	.453	.120	14.142	1	0.000	1.572***	57.2
Postdoc (had postdoc)	.137	.113	1.466	1	0.226	1.147	
Research I	.302	.374	.653	1	0.419	1.353	
Research II	.112	.399	.078	1	0.780	1.118	
Doctorate Granting I	-.127	.420	.091	1	0.763	.881	
Doctorate Granting II	.097	.401	.059	1	0.809	1.102	
Comprehensive I	-.845	.380	4.943	1	0.026	.430*	57.0
Comprehensive II	-.651	.553	1.386	1	0.239	.521	
Liberal Arts I	-.547	.426	1.649	1	0.199	.578	
Liberal Arts II	-.921	.432	4.553	1	0.033	.398*	60.2
Medical School / Center	.321	.452	.503	1	0.478	1.378	
Constant	-1.423	.490	8.426	1	0.004	.241	
Omnibus Tests of Model Coefficients			□²	*df*	*p*		
Step			140.322	18	<.0001***		
Block			140.322	18	<.0001***		
Model			140.322	18	<.0001***		
Goodness-of-Fit Test							
Hosmer & Lemeshow			12.364	8	.136		

*P < .05, ** P < .005, *** P< .001

*Note: (*Cox & Snell R^2 = .058. Nagelkerke R^2= .085. -2 Log likelihood = 2564.739

Summary of Quantitative Findings

A summary of the results of the four regressions has been provided in Table 4.15. As the summary table indicates, predictors varied greatly for the different forms of collaboration. Increasing age and years since earning the doctorate were only significant predictors for faculty members on the team level of collaboration. Neither gender nor postdoctoral research history were significant predictors for any form of collaboration. International respondents to the SDR survey had lower odds of collaborating at the team level and higher odds of collaborating at the international level than their U.S. citizen peers.

While field of study was a strong predictor of higher odds of collaborating at the team level for all three fields as compared to faculty members in the social sciences, only faculty members in the life sciences and engineering had higher odds of collaborating at the intra-institutional level. Field was not significant as a predictor for inter-institutional or international forms of collaboration.

Institutional type was a relatively strong predictor of collaboration at the team, inter-institutional, and international levels, but was not at all predictive for intra-institutional collaboration. This suggests that the vast majority of faculty members collaborate at the inter-institutional level, an assertion supported by the frequency data reported in Table 4.6, while institutional type has greater impact on the likelihood of collaboration on the other forms of collaborative activity. The broad variation with regard to predictors of collaboration among the four forms under study suggests that each form of collaboration has its own mechanisms and underlying motivations from the perspective of faculty members. These questions were explored in detail over the course of the individual interviews with faculty members. The results of those interviews are reported next.

Table 4.15

Odds Ratios for Collaboration

Dependent Variables	*Team*	*S.E.*	*Intra*	*S.E.*	*Inter*	*S.E.*	*Int'l*	*S.E.*
Age	1.019*	.008	1.002	.008	.993	.007	1.007	.008
DegreeYrs	1.093***	.022	1.029	.023	1.014	.021	1.016	.024
Gender (male)	.978	.093	1.209	.098	1.130	.091	1.216	.101
Tenure (tenured)	1.092	.123	1.196	.131	1.094	.118	1.336*	.128
Social Sciences (reference)								
Life Sciences	2.699***	.123	1.524***	.131	.983	.118	.779	.132
Engineering	3.127***	.140	1.539**	.147	1.108	.135	.844	.143
Physical Sciences	1.884***	.129	.827	.133	.791	.128	.897	.145
International (non-citizen)	.785*	.118	.798	.121	1.202	.118	1.572***	.120
Postdoc (had postdoc)	1.170	.107	1.017	.112	1.029	.104	1.147	.113
Research I	3.908***	.355	1.350	.375	3.113***	.343	1.353	.374
Research II	2.574*	.380	1.372	.405	2.906**	.372	1.118	.399
Doctorate Granting I	2.527*	.395	.855	.413	1.701	.381	.881	.420
Doctorate Granting II	3.067**	.384	.977	.401	2.595*	.372	1.102	.401
Comprehensive I	2.046*	.353	1.194	.374	1.173	.341	.430*	.380
Comprehensive II	1.568	.470	1.012	.497	.686	.463	.521	.553
Liberal Arts I	1.336	.389	1.360	.415	1.364	.376	.578	.426
Liberal Arts II	2.080	.384	1.036	.404	.821	.371	.398*	.432
Medical School / Center	10.372***	.535	2.368	.516	2.246	.425	1.378	.452

* P < .05, ** P < .005, *** P< .001

CHAPTER 5: RESULTS OF THE QUALITATIVE ANALYSIS

Chapter 5 describes the results from the qualitative stage of the study. The goal of the chapter is to answer each of the four qualitative research questions with interview data. The questions are:

- *What forms of collaboration are participants engaged in with regard to their research activities?*
- *What are the mechanisms early-career faculty members employ in the development of their collaborative research networks, how are these networks maintained, and why are collaborations pursued?*
- *What is the perceived relationship between the collaborative work done in graduate school, the postdoctoral research period (if applicable), and the respondents' faculty careers?*
- *Do faculty members with international status and domestic status differ in how they perceive the constraints on and opportunities available to them as they relate to the development of collaborative partnerships?*

Forms of Collaboration

To answer the first question regarding forms of collaboration, an expanded conception of how faculty members define collaboration in their lives must first be established to understand the divergences between the preceding quantitative data and the data collected from in-person interviews. A discussion on how interviewees defined collaboration for themselves is followed by a discussion of the types of collaborative activity faculty members self-reported engaging in.

A Broader Definition for Collaboration

As explained in Chapters 1 and 3, collaboration was openly defined for the purposes of the interviews and explained at the outset as working with other scholars in the performance of research at the departmental, intra-institutional, inter-institutional, and international levels. Team-level collaboration as reported in quantitative phase of the study was explicitly included in the departmental label. While it was assumed that collaboration thus defined would frame a discussion on collaboration that would enable an easy comparison to the data from the 2006 SDR, interviewees saw collaboration and their engagement in its practice in a much more complex and expanded way.

Part of the response differential between the collaboration data reported on the SDR in Chapter 4 and the results of the interviews reported here, is undoubtedly due to the opportunity to negotiate the meaning of the concept of collaborative research in the interviews. Just as Marginson (2009) notes that knowledge becomes structured and imbued with new meaning by the people it passes through, so too do the terms explored over the course of an interview. While the definition of collaboration articulated at the start of the interviews was similarly broad to the questions related to collaborative activity on the SDR, interviewees were able to engage in a dialogue about the meaning of collaboration and reaffirm with the interviewer the broad nature of how collaboration was being defined for the purpose of the study. As a result, respondents maintained broad notions of collaboration and discussed how they saw it infused in nearly all facets of their scholarly work.

Faculty members articulated collaboration as a complex research process with diverse outcomes, rather than as a uniform means toward accomplishing a set of well-defined and/or easily measured outcomes such as co-authorship and active citation of colleagues' articles. It is

possible, for example, that respondents on the SDR assumed that NSF was only asking about collaborative research activity that led to tangible outcomes. Naturally, completing the survey with this perspective would limit responses significantly. If a survey respondent had co-authored a paper with a colleague abroad, they would have indicated "yes" to the question regarding international collaborations. If that same respondent had simply talked about a research idea with a colleague from abroad at a conference and then written a paper by herself, she may or may not think of that as international collaboration for the purposes of the survey.

Illustrative of a broader role for and possible forms of collaboration as understood in the interviews, one faculty member remarked, "Students and faculty are coming here from a variety of perspectives, and therefore you have to adjust. I mean that made me a better – a better teacher, right? I have to adjust my pedagogy a little bit as well. So, I think that's a form of collab – a small "c" collaboration – that is maybe not as relevant to research, but is still relevant to being in a university setting, um, where people from different backgrounds and upbringings actually need to be collaborative and need to be aware of these different ways of approaching work and…issues."

Taking up this comment on small "c" collaboration and its transformative effect on faculty members' pedagogical approaches, collaboration in teaching was a major theme to emerge from the interviews, and this type of activity seemed to lead to an expansion of intra-institutional, as well as inter-institutional collaborative networks for respondents. An Associate Professor from the social sciences reported, "I've team taught, so I have collaborated with folks [in another academic department] in that way. So there are levels of collaboration that are unexpected and they [collaborators] don't necessarily show up as co-authors, but certainly have been fundamental to the development of [my] ideas." She continues, "We got a [institutional]

grant to develop a course together, which we would not have done. We've developed this course, we've taught this course, we'll teach it again. We talked this weekend about why can't we turn it into something that's a research thing. Um, but we are still strapped, because she's a historian and I'm still workin' on the last ten years. But even though we'll probably never publish anything together, I always send my grants to her to read… It's also a very rich intellectual collaboration."

This interview demonstrates the powerful nexus of teaching and research, as well as the broad types of collaborative engagement that faculty members become involved in at the intra-institutional level and beyond. It also makes it clear, however, that not all collaborative activity results in products in which all contributors are or can be publically acknowledged. There are exceptions, however. A faculty member recounted how co-teaching with a faculty member in another department led to both joint grant applications and co-authored papers. Through searching for a graduate student assistant to hire on an interdisciplinary research project, a faculty member in engineering learned about the research of a faculty member in the biological sciences. What began as a search for a student research assistant became a very productive collaboration between two faculty members from opposite ends of the university campus. The assistant professor in engineering explained, "He give a guest lecture in one of my graduate classes and I know more of his work and then we start writing grant proposal together and also a paper together."

Over the course of the interviews the important roles that colleagues, students, and mentors have played in faculty members' lives came to life in all its richness and complexity. This finding was an important realization, and enabled this research to broaden its focus on the forms and processes of collaboration writ large, rather than narrowing the focus to forms of

collaboration that can be tracked to tangible and more widely recognized and appreciated outcomes. As was emphasized at the beginning of this dissertation, the goal was to focus on the actual doing of collaborative work, not on the byproducts of collaborative processes.

Self-reported Collaborative Activity by Collaboration Type

In contrast to frequency results from the SDR data, which indicated strong variability in participation rates among the four types of collaborative activity, 19 of the 20 interviewees reported engaging in all four forms of collaborative research activity (departmental, intra-departmental, inter-institutional, and international) in the performance of their research. This was regardless of professorial rank, years on the job, gender, postdoctoral research background, field, or citizenship status. The fact that fully 95% of interview respondents reported engaging in all four types of research collaboration reinforces the notion that there were significant interpretative differences between how survey respondents answered the collaboration questions on the 2006 SDR, and how interviewees explained their collaborative research habits in semi-structured one-on-one interviews. It should be remembered that for both the survey and in the interviews, each form of collaboration was considered independently and a respondent or interviewee could differentiate between the forms of collaboration he or she had engaged in and the forms he or she had not engaged in. The overall collaboration patterns for the interviewees are reported in Table 5.1.

An interview with an associate professor in the social sciences brings into focus how the four forms of collaboration fit into her own academic life. Her comments also encapsulate well the reflections of many of her colleagues at the university. At the departmental level, this professor described her collegial collaborations as highly research-related and perhaps more technical in

nature. She reported going to her departmental colleagues for feedback as she developed new research questions, sought advice on research design and strategies for engaging in field work, and for insights related to field-specific theory that she was perhaps less familiar with.

Table 5.1

Interview Participant Characteristics Summary

#	Gender	Citizen	Field	Rank	Postdoc	Team	Intra	Inter	Intl	1st Exp
1	F	US	Soc Sci	Associate	No	Yes	Yes	Yes	Yes	UnderG
2	M	INTL	Engineering	Assistant	No	Yes	Yes	Yes	Yes	Grad
3	M	INTL	Life Sci	Assistant	Yes	Yes	Yes	Yes	Yes	Grad
4	M	INTL	Phys Sci	Associate	Yes	Yes	Yes	Yes	Yes	UnderG
5	F	INTL	Life Sci	Associate	Yes	Yes	Yes	Yes	Yes	Grad
6	F	INTL	Soc Sci	Assistant	No	Yes	Yes	Yes	Yes	Grad
7	F	US	Soc Sci	Associate	Yes	Yes	Yes	Yes	Yes	8th Grade
8	F	INTL	Soc Sci	Assistant	No	Yes	Yes	Yes	Yes	Grad
9	F	US	Engineering	Associate	Yes	Yes	Yes	Yes	Yes	Grad
10	F	US	Phys Sci	Assistant	Yes	Yes	Yes	Yes	Yes	Grad
11	M	US	Life Sci	Associate	Yes	Yes	Yes	Yes	Yes	UnderG
12	M	INTL	Engineering	Assistant	Yes	Yes	Yes	Yes	Yes	UnderG
13	F	US	Phys Sci	Associate	Yes	Yes	Yes	Yes	Yes	UnderG
14	F	INTL	Engineering	Assistant	Yes	Yes	**No**	Yes	**No**	UnderG
15	M	US	Life Sci	Associate	Yes	Yes	Yes	Yes	Yes	Grad
16	M	INTL	Life Sci	Assistant	Yes	Yes	Yes	Yes	Yes	UnderG
17	F	INTL	Engineering	Assistant	Yes	Yes	Yes	Yes	Yes	Grad
18	M	US	Phys Sci	Associate	Yes	Yes	Yes	Yes	Yes	UnderG
19	M	US	Phys Sci	Assistant	Yes	Yes	Yes	Yes	Yes	Grad
20	M	US	Soc Sci	Associate	No	Yes	Yes	Yes	Yes	Grad

Most of the collaboration at this level reflects engagement with colleagues that results in less tangible outcomes. These processes help with the formation and processing of ideas, the development of new research projects and with the working out of logistical details related to the actual conduct of research.

At the intra-institutional level, this professor saw her collaborations as more intellectually driven and expansive. These might entail monthly or weekly exchanges on general research

ideas, book and article recommendations, and the sharing of theory or strategies from farther afield. The focus at this level was explicitly more interdisciplinary. She was quick to point out that neither her departmental or intra-institutional collaborations had resulted in collaboratively produced articles, but had profoundly affected her writing, grant applications, and other intellectual endeavors such as teaching. This was a common theme across the interviews.

At the inter-institutional and international levels, this associate professor felt that collaboration lent itself toward more joint publications and presentations that could be easily identified as co-produced. A more junior faculty member in the same academic department who had just completed her third-year review as an assistant professor also emphasized the importance of both inter-institutional and international collaboration on such things as conference panels for their professional associations. These themes will be explored in more detail in the section of the chapter that examines the motivations behind various forms of collaboration, the gains from such collaboration, and the complex process of establishing reciprocity between researchers.

The sole exception to the comprehensive collaboration patterns reported by those in the interview pool was an international female assistant professor of engineering in her first year of employment as a faculty member at the university. This faculty member completed an eleven-month postdoctoral research appointment in the U.S. prior to beginning her faculty career. She reported that she had collaborative research proposals in the development phase both within her academic department at the university, as well as with a faculty member in a similar academic department within a different U.S. engineering program. She identified herself as the Principal Investigator on both of these collaborations, and both were NSF funding proposals still under

review. She reportedly did not have any active intra-institutional or international collaborations at the time of the interview (in the spring semester of her first academic year).

For the departmental collaboration, the faculty member reported that this came about through the course of regular faculty research meetings within the department. She noted, "We usually have meetings and there we discuss something interesting and when we see some proposal of course we gonna discuss and say maybe this is a good place to go to submit some research proposals. It usually goes like that way." She also stated that her partnership with the colleague in her academic department was the result of complementary overlap in their areas of research so that it made a strong NSF proposal.

In delving more deeply into her inter-institutional collaboration within the U.S., this was the result of continued collaboration with her Ph.D. advisor. She reported continuing to engage in active research with him because, "He is exactly doing the area I'm in." However, she did note her concern with maintaining this collaboration in the medium- to long-term and the need to establish an independent research reputation in her field. In her words, "I think independent [research] is very important so I don't want to like keep – I mean – collaborate [tion] with him [Ph.D. advisor] is very good, but I don't want to depend on him to do the research every time…I'm not going to collaborate with him anymore because I have to be independent."

The exceptional case example just reported is highly illustrative of how a new faculty member quickly begins to establish the collaborative ties that enable her or him to engage in all forms of collaborative activity studied. Several interviewees reported stronger departmental research ties in their initial years as faculty members, and many also continued to maintain strong research collaborations with their former Ph.D. advisors and postdoctoral research supervisors, even at the associate professor level. Keeping this in mind is important when

considering the frequency with which early-career faculty members report engaging in departmental and inter-institutional forms of collaboration. Both forms may represent the easiest kinds of collaboration to engage in as newer faculty members. This may be due to the proximity to and frequency of contact with colleagues at the departmental level, and to the maintenance of existing research linkages made prior to beginning a faculty career.

A tenured associate professor in the social sciences sheds some light on the complex set of challenges and pressures to collaborate that newer faculty members experience. He explained, "You have so much hierarchy built into it [faculty careers], right? So it doesn't just end in graduate school. You are a junior prof and you know – should I collaborate with a big senior name [in the field at large] so that I can get my name out there? Or should I, you know, collaborate with a senior colleague in my department, right?"

In many cases, maintaining collaborations with former Ph.D. advisors and postdoctoral mentors seemed to help maintain those connections with more senior members of the field at large, while establishing connections within the academic department helped satisfy that motivation to become a fully engaged, active, and known member of one's new academic department. The challenge of time and establishing critical research connections is one that people reportedly face from their very first semesters as faculty members, as illustrated above by the new assistant professor indicating an intention to maintain collaborations with her doctoral program advisor only so long as it takes to establish her independent faculty research career. In the words of another new assistant professor just staring out on his faculty career, "I think as faculty you can often be fairly isolated like in your area, and especially when you are first starting out you sort of have to be to some extent. Like there is certainly more opportunities for graduate students to informally hang out with one another than there are for faculty members."

This lends further context to those faculty members who reported, at least initially, maintaining their collaborations with Ph.D. advisors and postdoctoral mentors as a principal source for inter-institutional collaboration within the U.S. This makes sense since those connections are already established and can be tapped into right away as junior faculty members set up their research programs.

As conference attendance reportedly began to pick up for faculty members, so too did the forms of collaboration that they engaged in with colleagues from abroad and with U.S. institutions beyond their doctoral-granting or postdoctoral institutions. Furthermore, as faculty members reported becoming more engaged in their own institutions through service and teaching, they articulated an expansion of their collaborative research efforts at the intra-institutional level. This is illustrated in the remarks of an associate professor in the social sciences who stated:

> We are still in an inherently collaborative enterprise here, where we are on committees together, talking about teaching, or we are talking about starting up programs or advisory boards or oversight committees or steering groups or whatever. That's a form of collaboration as well, and within a university setting where to the extent that the culture comes in there, it's nice to have that, because that actually keeps us from getting too sort of narrowly focused.

What is remarkable in the fact that all but one of this study's respondents reported engaging in all four types of collaborative research activity, is just how fast faculty members are able to expand their networks beyond their departments, Ph.D. advisors, and postdoctoral mentors. Quite quickly, it seems, faculty members are able to engage faculty colleagues within their institutions from different disciplines, as well as colleagues from a broad range of institutions within the U.S.

and beyond. The two other faculty respondents who were also in their first academic year at the university described collaborative activity that spanned the range of possibilities examined in this study.

The next two major sections of this chapter explore the self-reported mechanisms faculty members use in establishing and maintaining those increasingly broad collaborative connections, as well as the motivations behind engagement with others in the performance of research.

Mechanisms for Collaborative Network Development and Maintenance

In the initial stages of this research, the second research question, "What are the mechanisms early-career faculty members employ in the development of their collaborative research networks, how are these networks maintained, and why are collaborations pursued?" was expected to yield succinct answers to how, when, and why researchers engage in different forms of collaborative activity. Over the course of the interviews, however, it quickly became clear that the answers to this question are highly complex and consist of several interrelated components. For clarity, therefore, the results for the second qualitative research question are reported in two separate organizational sections. The first section focuses on how and where faculty members begin their collaborative partnerships and how they are maintained and expanded upon over time. A second section explores the underlying motivations behind and pressures to engage in collaborative activity and the perceived gains achieved through such work.

Over the course of the interviews, a great deal of emphasis was placed on developing and maintaining the collegial networks needed to facilitate collaboration at the four levels under study. From the assistant professor level through the associate professor level, networks were

seen as critical to generating ideas, finding new graduate students, succeeding in the grant application process and finding out about other collaborative opportunities, gaining recognition for work, and finding the collaborators who can bring essential skills, equipment, technology, and knowledge to a project. An associate professor in the life sciences put it this way, "Ultimately, the [research] game is still played, you know, in person. So if you get to meet somebody you see how they think, you see how they evolve in the way that they approach things – it's a lot easier than just sending a cold email." He continued, "You know in order to be good at the job you had to figure out who was doing what…Well, you gotta go to meetings where those people hang out, and so that's how that builds…You gotta network with people. You gotta talk. The people that aren't willing to do that are the ones that are suffering."

Several mechanisms were articulated for actively developing research networks. One faculty member, an assistant professor in engineering, talked of "cold calling" in order to get himself connected with a network he felt was essential to his research. "Seventy-five percent of my collaborators are [where I] just I pick up a phone call or I call them. Only 25% are somebody through someone," he stated. In probing further, the recipients of phone calls were initially identified through articles that they had published. By far, however, the majority of faculty members interviewed found collaborators through a more complex human network.

Tapping into the Ties of Existing Colleagues

This complex network took on a number of forms. Several professors mentioned getting connected to new colleagues through former supervisors in graduate school or during their postdoctoral research years. An assistant professor in the life sciences, for example, spoke of the software he had helped develop with his postdoctoral research mentor. The mentor and the

software served as bridges between this faculty member and an extended network of others who had also served as postdocs with this mentor at various times and who continued to work on different aspects of the software. He explained, "The main lab in which this software originated was the lab where I did my postdoc…So that professor is now extremely well known. So he's placed a lot of his former students in faculty positions and each of us take with us the software and we co-develop the software…So everybody knows who's working on what and even more to the point…is that we have an annual software developers meeting and we all know each other because we all had [the same postdoctoral mentor]."

This example shows how the postdoctoral experience can serve multiple roles with regard to developing a research network, from gaining the experience and connections necessary in order to earn a faculty post, to becoming incorporated into a larger research network through affiliation with a well-known and respected mentor. The connections established between this faculty member and other faculty members across the U.S. were not all direct connections [although some were for this professor and colleagues who had served as postdocs concurrently with him], but made through a common affiliation with one particular person, lab, and research tool.

Other faculty members developed their research networks by tapping into the existing knowledge networks of their more senior colleagues on campus. An international faculty member in engineering explained it this way, "We [people in the department] have more senior faculty and they have very good network with…experts in other areas. They usually know who is expert and they gonna contact them [for me]." Once again, this demonstrates how the indirect connections of colleagues [weak ties for the faculty member in question] can develop into productive and strong direct research collaborations. Similarly, a social scientist just starting her

career at the university described how her senior colleagues in the department were connecting her with colleagues at the intra-institutional level by referring her as a resident expert on their research projects. By serving as a statistics consultant on projects through her colleagues' referrals, she was rapidly expanding her campus networks.

Another social scientist who had been working for the university for several years and had recently undergone her third-year review also spoke to the importance of the referral network among her colleagues. She explained, "Even if you have the idea, the way you think [about it], you know, do I know anyone out there who can help me to collaborate to actualize this project that I want to work on? You probably immediately gonna screen all those people who you know and then you are probably going to contact people you know asking them if they can refer you to someone they know. And it is through these…people's networks that you are going to arrive at the potential collaborators." She goes on to explain that making connections through other people's networks helps to establish relevant networks in spite of an individual faculty member's lack of direct knowledge of relevant members of the research community, or poor networking skills. She concluded, "In most of the instances you do have to have this kind of personal touch or connection," referring to the help of a third party or intermediary in the development of a new research network.

Research Centers and Personal Mobility

In addition to senior colleagues on campus, research centers served a major network expansion role for many of the faculty members interviewed in the social, physical, and life sciences. In their descriptions of how centers affect their collaborative research networks, faculty members spoke to the role centers play in bringing together faculty scholars from different

disciplines on campus, scholars working in related disciplines from other universities, and prospective partners in industry with specific needs, interests, and resources.

Mobility was also seen as critical to network development and highly related to the roles that centers play. Excerpts from an interview with an assistant professor in the life sciences explain how. In his words, "Every time you move you are in a new scientific community [knowledge hub]…As a graduate student I learned about everybody's research program. So when it comes time to that I'm thinking oh I wish we could do this particular experiment, if I know somebody at [my graduate program] he's in my network." He went on to describe his networks from his years as a postdoctoral researcher and then summed things up by saying, "I think the mobility does encourage people to think outside of their geographical location…It expands your network and that alone might be responsible for more collaborations." This idea of geography-bound research centers speaks to the notion that knowledge hubs exist and of collaboration as a means to tap into multiple knowledge hubs in the performance of one's research.

An associate professor detailed his own professional development and the progressively expanding nature of research networks. This progression brings into focus many of the pieces described above. He described the initial stage of his network development in this way, "So when I started [as a faculty member] I probably had much more of a collaboration network with former grad [school] friends…And the collaboration, at least when I started, within the department setting, was walking down the hallway, talking to one of my colleagues immediately. Not just about topics, but just advice in terms of expectations for research and tenure and those kinds of things." At this stage he was focused on maintaining the collegial networks he had

developed prior to beginning his professional career and on developing ties to his new academic department.

As time went on, he described the expansion of his network in this way, “I’m not exactly sure if I’d call it snowballing or what, but I started taking on more committees, or to go to the locations of intra-university collaborations or talks [references specific centers on campus]. Then when I started meeting with those people then I not only had opportunities to be on committees for dissertation work or to give lectures in classes outside of my department, [but that] would start the conversations going with them [broader network of colleagues].” Another colleague from the life sciences explained it this way, “ You gotta go to meetings where those people hang out. And so that’s how that [network] builds.”

Conferences

Despite those who argue for the death of distance theory and assert that information technology is rapidly making face-to-face collaboration obsolete, every interviewee felt that conference attendance was absolutely critical to networking and the development of research collaborations. As one informant put it, “Sometimes you can send email and you know that works well for some cases. But sometimes it’s better to have [a] face-to-face meeting. Collaboration is not just you do work with somebody. There are also some personal things…I do computational [work] and sometimes I need to argue with experimental people [in person].”

Conferences served to connect people who did not know each other previously, were an important opportunity to work out the theoretical and logistical details related to collaborative research projects, and served to introduce new concepts and collaborative research opportunities to faculty members from different places around the world. As one life scientist put it, “Given

my druthers, and email is wonderful and great in terms of meeting up with people [virtually] and basically facilitating interactions overseas. But ultimately, what is going to be best is a face-to-face meeting at some particular phase to start our collaboration." This interaction was seen as critical for gaining exposure to the latest research, and as a physical scientist described it, essential to the development of the "cocktail napkin with the idea" phenomenon.

In terms of connecting people who did not previously know each other, several faculty members spoke of discovering colleagues engaged in similar or complementary work at conferences. This took on a number of forms. For example, serving on conference panels related to a particular theme was seen as a way to discover and bridge the gap between complementary areas of research. A social scientist, for example, related how her service on a panel brought her attention to the work of another faculty panelist in a different state, which eventually led to a jointly edited book. As she reported it, "I was at a conference, on a panel, with my colleague from Delaware…I looked at her and said, we should do a book. And she said, why don't we just do another conference panel together, you know, like get more of us together. And we did a[nother] conference panel together, we pulled all these people the following year and [a publisher] approached us and said why don't you do a book. So it worked out that way, that we literally just ended up on a panel together."

Establishing first-time connections was a theme that kept coming up across the interviews and across fields. Not all connections were immediately direct, however, lending more support to the weak ties concept. For example, an international faculty member in engineering described how he had attended a postdoctoral researcher's presentation at a conference and was eventually connected with the postdoc's supervisor. As he described it, "The reason I start[ed] a collaboration with a team in Columbia [University in New York] – I went to a conference and a

postdoc from that team give a talk and the topic is exactly what I'm interested in. And also I give a talk and the talk [was] exactly what **they** are interested in. So we kind of naturally have this hallway conversation [at the conference]….I see a proposal [later] from NSF and then write to the postdoc and say we have this opportunity…would you mind to join me? And then the postdoc talk to the PI [Principal Investigator] and the PI is interested and we start the phone conversation. We divided the work, and wrote the grant."

In a very similar story, a physical scientist related how she was presenting at a conference and a postdoctoral researcher in the audience made a suggestion that not only led to a highly productive research collaboration, but solved a research problem that she had been struggling with for some time. As she described the occurrence, "It's just amazing! One of my most high profile papers came from a talk I gave…It was like we are observing this change and we don't know what it's from and some postdoc came up to me afterwards and said, well, you know, I have some data that's showing you know that [the unexplained phenomenon] this event is happening at the same time as you are seeing that, so maybe they are linked. And you know, we **never** would have made that connection had it not been for that meeting."

Conferences were cited as a major factor in the development of international collaborations as well, and for international faculty members seemed to have an exponential effect on establishing international collaborations in some instances. For example, an international faculty member in the life sciences spoke of attending conferences in Asian countries [Japan] and making new research connections there, and then using that as an opportunity to make a quick stop to his home country [Korea] to visit family and prospective collaborators in his country of citizenship. The collaborations to emerge from international conference travel and family considerations are illustrated well in his remarks, "I happen to visit

Korea every March because there is a conference in Japan so they invite me and they pay for everything, so that I don't have any excuse not to go. And my parents, they just hate me if I don't go after [Japan]. Then [therefore], I use that as okay, this March I visit Korea for a certain period of time and I visit maybe two [or] three universities."

Similarly, conferences were seen as dependable places to connect with familiar colleagues on a regular basis. Just as the international faculty member routinely attended a conference in Japan each March and used this to maintain his family and faculty connections in his nearby home of citizenship, Korea, nearly all faculty members spoke of annual conferences as a place to reconnect with colleagues and touch base on collaborative projects. In the words of one faculty member, "Having that face to face time is pretty critical." Interviewees discussed how collaborative papers, presentations, and future research ideas had emerged from conferences and post-session discussions with colleagues over coffee or a beer. This was an assertion articulated by faculty members across the interviews. A social scientist explained that conferences are good for meeting people to discuss ideas after talks. While she claimed that email was good for post-conference follow-up, in-person communication was essential for presenting and working out new research ideas, as well as garnering interest in participating in a project from a colleague.

For U.S. citizens, U.S.-based conferences were an important venue for meeting international collaborators. As an engineer put it, "Yeah, all of these people [collaborators] I know internationally, I've met somewhere when they have come to the United States [for a conference]. An assistant professor in the physical sciences explains that the big conferences in her field in the U.S. attract scientists from all over the world. Many of the international collaborations mentioned by U.S. citizens and international faculty members interviewed were

developed through connections made at international conferences based in the U.S. In other words, since the U.S. is a knowledge hub for so many fields, citizenship status and / or connections abroad are not as critical to establishing international research collaborations if one is attending the big conferences in the field that attract researchers from all corners of the research realm.

Several researchers spoke directly to the social networking opportunities afforded by conference attendance. Conferences were not only seen as a way to keep connected to old colleagues and classmates, but as an opportunity to see "who's out there" and "what they are doing." Furthermore, conferences were seen as important to learning about new prospective students, helping students enter into the realm of academia, gaining referrals of postdoctoral researchers from colleagues, and the like. For students in particular, one faculty member described conferences as essential for students' "socialization into the profession."

Not all conferences were seen as alike, however, when it came to the networking opportunities they afforded participants. Conference size, for example, was seen as a major factor in how a particular conference could be used to maximum advantage by an attendee. A physical scientist explained the importance of size this way, "There is a wide variety of conferences and they are good for different things. The national meeting of ACS [American Chemical Society] is so big. [There's] too much going on for much conversation. Very little interaction, but it's good for meeting [prospective] grad students, postdocs, hearing papers and [seeing] posters. But [at] the Gordon Conference of 150 people, you meet for 6 days on a campus…So you talk, and discuss. Conversation over beer helps develop interactions with people. Close quarters make a big difference."

Teaching

Teaching also reportedly served to build deeper inter-institutional connections between faculty members in the same discipline and, for at least one pair of collaborators, led to the production of a scholarly article in a completely different area of scholarship. An associate professor in the physical sciences reported receiving a biocomplexity grant from NSF that required the involvement of several U.S. institutions, many researchers, and the development of project-related pedagogical materials. The grant activity and the exciting pedagogical materials that resulted led to the decision by two of the faculty members to co-teach a question-based experimental course. Students from each school ran the same experiments over the course of a semester, presented the results to each other via distance learning technology, and were responsible for developing research questions for the other institution's team. The result, "Was a very complicated way to teach a class, but it was great and it worked out very well and we ended up writing a paper to a pedagogical journal on teaching science," reported the university professor.

These four examples of collaborative teaching and teaching leading to collaborative research and pedagogical transformation point to the strong role that students play as a conduit and catalyst for collaborative scholarly engagement among faculty members. This was a dominant theme in the interviews and students clearly serve in myriad ways to bring faculty members together as collaborators at the departmental, intra-institutional, inter-institutional, and international levels.

Graduate Student Mentoring

Several informants discussed how graduate student mentoring often leads to collaborative research and joint publications. A faculty member in the social sciences reported, "Students – we throw to each other. I sent my student from here to work with [a professor in another department at the university] and made sure she knew [professor's name]… We haven't all published something…but we are very cognizant of each other's work and feel, I feel like we are close colleagues in a way that you know we just wouldn't have been before." Similarly, a professor from the physical sciences discussed how he refers his students to other faculty members within the department and even abroad who have mentoring styles or research programs better suited to the student in question so that they get the support that they need. These students often return, however, and ask if the referring professor would consider co-supervising the student's thesis or dissertation, which brings the faculty members themselves closer together in an effort to support the student. The professor from the physical sciences explains, "I think some collaborations are very easy. When everyone's ego is in check, everybody sort of has their eye on the prize or a particular student's thesis or uh a manuscript outcome, those ones are actually really easy. A student initiated some collaboration for me at the University of Southern Denmark with somebody who is, you know, National Academy in the U.S. and a very intimidating figure in my mind, but so easy to work with. It's like unbelievable collaboration to the point where we are still ongoing collaboration long term now all because of a student."

Another faculty member from engineering discussed how graduate students can serve to jump-start areas of potentially fruitful faculty collaboration between academic departments by engaging in the preliminary exploratory phases of the research and laying the groundwork for faculty members by building the basic connections. Sometimes it is even the initial relationships

between students themselves that serve to bring faculty members from disparate units on campus together for a collaborative enterprise. By way of example, a physical scientist recounted that a graduate student from another department in the sciences, "was friends basically with one of my graduate students and knew what we were doing. So it [the collaboration between faculty members] came through that [student] network."

In other instances, however, the graduate students collaborating with each other become the true collaborators, while the respective faculty members remained relatively disengaged from each other. Discussing an international research collaboration involving field work in Southeast Asia, one professor remarked, "We [the U.S. faculty] don't rub off on the faculty [abroad in Southeast Asia] as much as we would [like], but what we tend to do is pair my grad students with some of their grad students and there is all this cultural – scientific cultural exchange."

Just as it has been mentioned that new faculty members will often maintain research collaborations with their doctoral program advisors, especially in their early faculty careers, there was substantial evidence of highly productive collaborative research between faculty mentors and the students they were mentoring at the time of earning the degree. One faculty member in the life sciences explained, "You know my graduate students or my technicians or undergraduate students that do research in the lab, we always try to get it to a publication." This same faculty member, an associate professor, also made it clear that her closest collaborator was her own Ph.D. advisor from her graduate school days.

This was a pronounced theme across many of the interviews and extended to all four disciplinary categories. A social scientist at the assistant professor level discussed her recent shift in focus among her research collaborations toward her graduate students. For them, to paraphrase her remarks, collaboration with their professor is important because it is good experience and it

gets their names on publications and on conference presentations. The professor was also quick to point out, as were several other interviewees, that the products of collaboration with students also look good on the faculty member's vita. This theme of active collaborations with students was expounded upon by many of the interviewees and the sheer volume and diversity of situations was quite pronounced. Some faculty members discussed how their students' dissertations were spin-offs of highly directed research related to a larger externally funded project. Others emphasized their own roles as directing the research and securing the funding, while it was the students' responsibility to do the actual laboratory bench work and the write-up of results. As one professor stated it, "Students and postdocs, they tend to be engaged in the chemistry. The professor is the PI, the manager, so the student and postdocs do the bench work." Similarly, another professor explained, "I don't actually do much of my own research. I really direct the research and so – um – the real work, and I sort of lend some ideas to it, but the real work is done by the students. And so um, say 85 or 90% of the work in my lab is done by graduate students, or the productivity comes from graduate students…It's the process of making myself obsolete from their careers."

In the physical and life sciences especially it was clear that the laboratory served as fertile ground for both expanding the training of graduate students from other departments, and for increasing the capacity of the labs of their colleagues. Demonstrating the level of lab mobility among students for training purposes, one faculty member stated that her colleague's graduate students were gaining training in her area of expertise by interning in her lab. "I can help advise a student to do that [type of lab work] if you want somebody you know that's trained that way to participate in your grant. And that, that's where people don't think broadly enough [about the value of collaboration]." In this example, the faculty member's point was that by opening up her

lab to a student in a different program, she was both training the student and, upon the student's return to his or her own lab, enhancing the capacity of her colleague's lab by transferring the newly acquired skills. This knowledge transfer resulting from student mobility between labs was referred to by several faculty respondents.

Graduate student mobility between labs was not confined to the intra-institutional context. A professor in engineering reported routinely sending her students to labs abroad for short periods of time to gain more training from her colleagues. Similarly, a faculty member from the physical sciences discussed her openness to colleagues' students from Europe as they sought to come to the U.S. for additional training. This type of student sharing activity was reported most frequently by faculty respondents at the associate professor rank, but it was not limited to faculty members of a certain discipline, gender, or citizenship status.

Motivations for and Gains from Collaborative Research

This section explores, respondents' motivations for engaging in collaborative research activity, as well as perceived gains from collaborative activity. The role of granting agencies in facilitating research collaborations will be discussed, as well as perceived changes in the nature of scientific research. Other factors affecting faculty members' motivations related to collaborative research, such as the tenure process, challenges within the academic disciplines, the pressure toward physical academic production, and the logistical and intellectual needs of researchers will also be discussed. Idea-centered and people-centered motivations for collaboration will also be explored as a dominant theme to emerge from the interviews. The final sections of this chapter will examine the more tangible and less tangible gains attributed to

collaboration and the various forms of reciprocity achieved by researchers engaged in collaborative activities.

The Role of Granting Agencies

When asking interviewees about why they engage in collaborative work, several consistent themes emerged. Foremost among them was the push by granting agencies to engage in collaborative research. To put this into context, an assistant professor in the life sciences described the pressure he has experienced from NSF to engage in collaborative research, "My NSF proposal, which was not funded, the main critiques was that okay – this person is doing in good computation – where is his collaboration on the experimental side? So I try. Young or experimental people [though] basically [made] no response [to my requests to collaborate]." This comment points to the challenge newly independent researchers face early in their careers to develop grant-related and highly strategic collaborative partnerships with colleagues in the pursuit of external funding for their research. This external pressure to collaborate seems to persist throughout faculty-members' careers. Referencing her mentor from her doctoral program, one associate professor spoke to his aversion to collaborative research but how he has, "actually broken out of that a little bit since that time because actually NSF and some of these funding agents – agencies – have required that we all work, I mean that we're not to get funded if we don't put together these larger [collaborative] projects, but I will say that I, um, was trained with his model of self-reliance…"

This agency-originated pressure to engage in collaborative research was especially pronounced in the life and physical sciences where there is more of a divide between the theoretical or computational side of research and the experimental or applied side. Another

assistant professor in the life sciences described it this way, "As far as fundable [projects], at least for NIH [the National Institutes of Health], they want to know about significance and innovation and approach. That's their three sections. And so, having a collaboration…makes it really easy to write the grant because what we are doing is the innovative part, the approach comes from our choice of [our colleague's] model system, and I copied and pasted [a different colleague's] significance section [from another proposal]." This demonstrates how researchers work to bring together good theory-grounded ideas from one environment with the technical experimental expertise of another environment to create an innovative, fundable and more holistic research project.

Just as agency requirements can bring scientists together in an effort to attract research dollars for innovative projects, those same funding agencies can serve to isolate researchers from each other who are working on the same project. An associate professor in the physical sciences explained, "This NSF project with my colleague in Minnesota, you know, I have driven a lot of it, and it's also been very independent because we had [only] two years. I mean it was a stimulus-funded grant. You know we had two years to get everything done and so in some ways we've had to – the communication – it's not that it's broken down, but we basically said okay you're gonna do this and I'm gonna do this, and it's been less of this interaction I think partially because there is not enough time you know for us to iterate a lot of the deliverables."

This focus on deliverables for granting agencies was mentioned by several interviewees. An associate professor in the life sciences, for example, explained that with agencies like NSF, grant renewals require evidence of results from prior support. Several faculty members acknowledged this and discussed the challenge of being prepared to produce those results independently when your name is on the grant, even if your collaborator/s don't come through on

their end. A life scientist articulated it this way, "You have consultants that you are going to pay some money [from the grant], but what if they don't come through? What if they all of a sudden develop other priorities? I mean you can't blame them, even though they might have made a commitment or not. But I mean then you have to be able to make it a successful project. You know – in spite of you know what others might do."

The other challenge faculty members frequently articulated with grant-driven collaborative research is that you can't adapt as well to new challenges or changes, whether externally imposed or internally derived. On the one hand, several respondents discussed how critical it is to be highly organized in large collaborations with roles articulated and point people established to keep the research moving forward in a productive and coordinated fashion. On the other hand, this same higher level of organization makes it difficult to remain "nimble," as one associate professor in the physical sciences put it.

One particular challenge articulated by a physical scientist who does collaborative research on climate change on an international level, is that funding cycles and work cycles are different depending on the country of origin for your collaborators. Most grant funding only goes to support researchers from the same country the agency is located in, so many international collaborations have multiple independent sources of funding involved. A frequently cited exception to this, are agency stipulations that require engagement with scholars from the country hosting the research or emphasize local dissemination of research findings. The challenge of having multiple sources of external funding from different countries is that it means that the members of the larger research team are expected to meet different criteria for success and have different timing and reporting expectations. This makes logistical coordination much more difficult, especially for field research conducted in highly remote locations.

Several researchers also mentioned the challenges of gaining external support for innovative collaborative research due to high levels of risk aversion on the part of the funding agencies. Publically supported agencies like NSF must show their oversight committees that they are responsible stewards of public funds. If they do not, they will suffer when it comes to appropriations time. The result is, "They won't fund something – they want stuff that is risky – but not stuff that is too risky," in the words of one assistant professor in the physical sciences. The challenge is to "show that it [the research project] already works so you have to have done the experiment to get the money to do the experiment," she continued. This conundrum is frequently solved through collaboration in which a faculty member will partner with a colleague who has an alternate source of funding and needs some help to accomplish his or her research goals. In exchange the collaboration partner is often willing to use some of his or her research funding to help the faculty member pilot a related project in the field.

Overall, most of the interviewees felt that the funding agencies played a positive role in facilitating collaborative research. The emphasis on developing external partnerships, for example, has meant that this university and other universities are providing the seed funding faculty members need to build those connections with colleagues beyond the institution. One faculty member in the life sciences mentioned how the university made it possible for her to hold an international research summit on campus to bring her collaborators together and develop new research proposals. Another faculty member in the physical sciences discussed how Brown University did something similar and paid for him to come to campus to iron out a new field research project abroad that will require external funding.

Similarly, agency efforts to facilitate dialogue among researchers in the early stages of developing new research initiatives were praised by the interviewees. NSF workshops in

particular were lauded as a good way to facilitate collaborative research, as well as grant recipient conferences hosted by agencies. The continuing importance of face-to-face collaboration will be discussed, later, but the role that agencies and institutions of higher education play in facilitating that interpersonal contact, either before receiving a grant, or in the administration of the grant, was highlighted by many informants as absolutely essential.

The Collaborative Nature of Scientific Research

Interdisciplinary Drivers of Collaborative Research. Another dominant theme to emerge from the interviews was an assertion that the nature of science has fundamentally changed and now requires collaboration. The character of this change was seen as multifaceted among the faculty members interviewed. Several informants, for example, spoke to the growing interdisciplinary nature of research today and the growing burden of knowledge that makes it impossible for any one researcher to have sufficient depth and breadth of knowledge to accomplish his or her research goals. In the words of one life scientist, "We need collaboration because the nature of science – scientific research is more interdisciplinary nowadays and as you know for science people grant is our life, right?"

In describing the growing interdisciplinary nature of science today, the same faculty member discussed how newer fields like computational biophysics require broad knowledge of multiple areas such as computers, biology, physics, and chemistry. At the same time, depth in these areas is critical if innovative and groundbreaking research is to be achieved. That is where many scholars report employing collaboration in their research. In the words of a more senior life scientist, "I don't think it can be done alone anymore. Especially given the topics. Not even the ones that we want to include in our research when we come across them in pathology or in

collecting, or whatever. Or even just molecular tools versus morphology. You just can't be expert in both of it. And therefore I think collaboration is a must."

When asked why he sought out departmental and campus collaborations, an assistant professor of engineering answered the question from the perspective of the actual research questions he seeks to answer through empirical research. "Everybody is doing a certain type of interdisciplinary work," he said, "The reason for that – in order to solve a problem there is no discipline. A problem is just a real world problem. There is no discipline. So if we break down the problem into pieces, then we start to see the disciplines there. But if we focus on the real problem, then we have to pull all these pieces together…No one has experience to do everything. So, I would think everybody have some certain need to do interdisciplinary collaboration – interdisciplinary research."

Networking with colleagues from other academic disciplines on campus was one way that faculty members worked to solve interdisciplinary research problems. The excitement of branching out into new areas through campus colleagues outside the department was captured quite articulately by a colleague from the social sciences. She explained, "I think the collaborations that I have here – I mean – this is **why** I came to [the university]. Because, it's such a rich intellectual environment and pieces of me are all over this campus. But there is no one just like me on this campus and there never will be, 'cause we won't get another hire like me. The pieces of me are fed, you know, wonderful meals. Wonderful rich intellectual meals here that keep me going."

Technical, Situational, and Expertise-Related Drivers of Collaborative Research. On a more technical level, collaboration was seen as critical to field work in the 21st Century. A

physical science faculty member engaged in international field work in remote locations stated that international collaborations were essential in order to acquire research permits and visas, to bring in needed expertise, to bridge language barriers, to help with site-related logistics, and to maximize limited and expensive research time in remote locations. In fact, according to her experience, colleagues from other subdisciplines had changed their research foci and more closely aligned themselves with their colleagues working in the climate change area to capitalize on a shift in the funding available to support research related to climate change. This shows the immense power that can be attributed to the research priorities articulated by granting agencies and how the funding itself can alter the course and nature of scientific inquiry. This was a phenomenon articulated by several interviewees, most markedly from the physical sciences.

Another transition articulated by faculty members engaged in collaborative research is a move away from a traditional bias toward the lone wolf scientist. An associate professor in the life sciences explained it this way, "Part of science is changing …it's a lot easier to collaborate now than it was back when everyone had to be kind of your own fiefdom and you have to do everything in-house. And I guess as a younger guy, I don't need to do everything else. I'm going to let people do what they do well and I'm going to do what I do well, and the sum total is going to make this better overall." A colleague from the same department explained further, "Collaborations happen most naturally when the different people involved can't do one part or the other, right? So then you are kind of forced to wait on the other person to deliver because you can't simply replace their contribution. So the collaboration is more out of necessity."

The social scientists, physical scientists, and engineers interviewed seemed to agree with their colleagues in the life sciences that innovative scientific research requires collaboration with scholars of varying expertise. A newer faculty member in the social sciences explained her own

role serving as a statistical consultant on campus for colleagues conducting research in clinical settings. Whereas her expertise lies in designing statistical protocols to understand the impact of clinical trials, her collaborators hold expertise on the construction and implementation of those actual clinical trials. By working together, they are each able to accomplish their respective research goals and acquire the necessary external funding.

This notion of bringing in collaborators with unique expertise on research projects so as to accomplish a research goal that is greater than the sum of the individual parts was a sentiment articulated by several of the interviewees. Irrespective of the pressure from granting agencies to collaborate, and despite the additional work and time that collaborative research often requires, participants in the study seemed to endorse collaborative research as critical to their work and articulated a level of excitement about the power of collaborative research that was unexpected. Several researchers did indeed remark that collaborative research seems to get published at a quicker rate and therefore has a more utilitarian benefit associated with it. However, others seemed authentically delighted in the power of collaborative research to take them to an entirely new level of research in which the impossible suddenly becomes quite feasible. This excitement is beautifully articulated by an assistant professor in the life sciences. He explained,

> So in real mice we are going to have proteins, we are going to have mouse memories that are established or erased by shining light **on the mouse brain**! And this is something that as a chemist that works with atoms he [a German colleague] could never do this. I could never do something like that. I mean really none of us had – are – it sounds like science fiction to all of us, it's so far outside the scope of what any of us could do. But he [the German colleague] assembled exactly the right team for this, and so this thing got funded because I

> mean it makes **perfect** sense to me why this thing would, because in bringing together exactly the right group of people where his part is totally feasible for him, my part is totally feasible for me, the mouse woman [in Canada], it's totally feasible for her to do the pieces she needs to do, and collectively we can do this thing that sounds like science fiction. And when it was scientifically reviewed they really had no criticism because even overall the thing that we are doing is amazing, you couldn't claim that any of us in particular would be unable to do the thing that we need to do to make this work…The one question is whether we'll be able to put together the pieces, but that's exactly the focus of this grant.

Discipline-Centered Drivers of Collaborative Research. For the faculty members interviewed, collaboration was often seen as a way to access and incorporate the perspectives of others from within the discipline into their research. The relationship between the perspective sought and the physical location of the collaborator, however, was quite complex and often seemed to work against conventional wisdom and the efforts of the agencies funding research. Take, for example, an associate professor in the social sciences. In describing her campus collaborations she stated, "I was hired [by the university] to be **the** [specialist] person [verbal emphasis on the definite article] and so my collaborations with people who are [in my specialty] are at other institutions. So in some ways, I think I've had to stretch more to work with people here [on campus], because they don't really fit into that [i.e. my] specific genre of academic research." Similarly, a woman hired into a position in the physical sciences described her hire as an explicit effort to bridge the divide between several different departments because of her unique interdisciplinary approach to her field of research.

This notion of being hired by the university because of a unique specialization was articulated by several faculty members, as was the assertion that in order to collaborate with people conducting similar research in the field, faculty members have had to reach beyond the institution's borders. In the words of a life scientist at the assistant professor level, "I do have collaboration in our department or inside our university, right? But the nature of what I'm doing I do more collaboration outside simply because we don't have many people that I could collaborate [with] here."

Looking to the outside to find collaborators with similar research interests and disciplinary backgrounds or methodologies is somewhat surprising when one considers the emphasis among many funding agencies toward interdisciplinary collaboration through the building of partnerships with multiple institutions. Illustrative of this point, a tenured American social scientist explained his own international research collaborations in this way, "I write in a tradition or an intellectual tradition or with a set of methods or whatever that tend to be more consumable or popular over there [the United Kingdom]…As a result, a lot of the people that I've extended offers to in terms of collaboration, they could even be Americans, but they tend to be people in the UK and European academies that were publishing in the same types of journals or whatever. And so – the transaction costs of having to start up – in a weird way, right? – of having to start up a collaborative enterprise with them are much less than it would be even walking down the hallway." Much the same sentiment was articulated by an international faculty member at the assistant level in engineering, "It's easier to speak the same language internationally – you know - the language of engineering…You know I did a collaboration on so called typhoon, which in the U.S. is called hurricane. It's basically about the same so, it's just a way of describing…we understand…it's [about] the wind."

Perhaps surprisingly, people referred to their collaborations within the department and intra-institutionally as often their most diverse, albeit within the same general discipline. One physical scientist referred to his department as an important sounding board for new ideas and concepts to ensure that they were not too far afield. When drafting a grant proposal or finishing a manuscript on a completely new topic he said he is, "much more likely to go down the hall with a draft of a paper or an idea and say 'hey – am I dumb? Am I gonna get hammered on this?' Sometimes someone [in the department] has a different skill set or an instrument or something."

This tapping into a nearby colleague's different skill set was an especially pronounced theme. An associate professor in engineering also referred to this, and indicated that she taps into campus collaborations to access different skills because the technology is more available and she has the opportunity to learn that new technology and incorporate it into her research paradigm. This point was also made by a life scientist who has brought in colleagues' expertise from Pharmaceutical Chemistry, as well as Medicinal Chemistry in his own research. In his words, "I didn't even know the difference between Pharm Chem and Med Chem for the first year and a half I was here because it's foreign to me. Now I know [because I have spent time with them and we have shared students]."

The problem-based approach to collaboration, which requires an examination of the research question first, breaks it down into skill sets or areas of disciplinary depth, and then leads into building the most appropriate team, was also a common approach to collaborative research engagement. A life scientist presented a perfect example of this approach in action, "[Departmental colleague] is a collaborator in…both of my departments. And so his expertise is mathematical modeling of ring assemblies, which is exactly what we needed for this project and in some sense we chose the project knowing what he did and sort of in discussion with

him…That's tremendous to have people around that can bring expertise complementary to ours…I let myself dream up projects that we can do with help from people at [the university]."

Similarly, a physical scientist stated, "You can get really great ideas just talking to someone in the hallway – so those are important ways to bring out new ideas and I guess with those informal ones they happen a little bit more." In other words, having colleagues with related field knowledge and a set of strong common understandings in the discipline, but different subspecializations or approaches, can lead to new and highly innovative collaborative research. This collaborative approach can even be broken out into different stages of a research project, especially within the sciences as a physical scientist explained, "At the departmental level, I mainly collaborate with an individual who does computational [work]. This is mutually beneficial – he gets a problem to solve and I get the solutions."

Tenure- and Promotion-Related Pressures Related to Research Collaboration

Tenure figured prominently in faculty members' narratives related to collaboration. For many, collaboration was seen as a hindrance as they moved toward tenure. For others, collaboration was a means toward earning tenure. For a more senior group of faculty members, collaboration was a welcome, exciting, and necessary development in their post-tenure research endeavors.

The assistant professors who participated in the study seemed to view collaboration as a double-edged sword in their efforts to earn tenure. On the one hand, as an assistant professor in engineering articulated, "Maybe I have this tenure clock tickling around my ears. So – um – I always looking for things with a tangible output." This remark reflects a common theme among

the assistant professors interviewed in that it shows a conscious recognition that time is limited and research output is critical.

On the other hand, there is also evidence that faculty members are thinking in the immediate and longer term related to their research careers. That same engineering professor explains, "International collaboration takes time, takes effort, and also it for long-term project. If for just three months or half year, it probably doesn't work, [not] worth the effort…For junior faculty members the first year and also for the international collaboration – yearly – both sides need to have some accumulation." This passage reflects the balancing act that assistant professors are trying to achieve in their research lives: to build momentum for a longer-term and sustainable research program, and to achieve the necessary research outcomes in the immediate term that are essential toward earning tenure. In the words of a different engineering assistant professor in her first year at the university, "If you really want to do research, you can't stop after 5 years, right? I mean you've got tenure and you still have to write grants, you still have to bring in money, so if you don't explore long-term collaborations, then, uh, that will fall through."

Reflecting back on her pre-tenure years, a social scientist explained that she perceived a bias in her academic department toward single-authored manuscripts. In her words it was important to her colleagues to, "establish that you can stand on your own two feet." This was a sentiment articulated by faculty respondents across the four academic areas under study. An engineering professor put it this way, "We still need to do our own work. So I think my personal goal is to maintain [a research] portfolio that I have paper [that generates publications] purely from my group. That's basically we are building our own shop." Similarly, a life scientist at the assistant professor level stated that it is critically important to establish one's own research specialty within the first four, five, or six years. This sentiment was reinforced by a tenured

associate professor in the physical sciences who claimed to have felt a great deal of pressure to put himself first on article publications [rather than his students] to ensure appropriate recognition of his scholarly contributions to the field.

This last point emphasizes a disconnect between actual collaborative research behavior and how this behavior is, or is not, identified within the context of research output. On the one hand, several faculty members reported a strong bias in their academic departments and across the university as a whole toward single-authored publications. A social scientist on a university promotion and tenure committee explained it this way, "I'm more of an anti-collaborative snob in the way that I evaluate people's work, in the sense that I think that they should still [do independent research], in addition to collaborating, which actually shows me that they are a versatile scholar – so I think that's important, they should also have some sort of independent research program that they are building upon…"

On the other hand, as was also articulated in the previous sections, the nature of science often requires collaboration and collaboration with students is a major component of that research process, especially in the sciences. Even in the preceding quote from an engineering professor, the collective work of the "shop" is seen as the work of the individual faculty member because he or she is managing the work, regardless of whether or not the faculty member is engaged in the actual bench work. This was articulated quite clearly by an assistant professor in the physical sciences who reflected, "So for promotion and tenure you have to have established yourself as the one with the reputation in some field. As the faculty member [running a student lab], being in the middle on a list of authors doesn't really help…My strategy I guess has been to mostly pursue projects where the papers will come out with my name last [the most prominent position]."

The perceived lack of authenticity in how the work of assistant professors is attributed [emphasizing the professor's individual role as opposed to the collective role of the collaborative team], was the cause of much frustration for several interviewees. A tenured professor in the physical sciences went so far as to say that tenure should be abolished, claiming that it, "stagnates in many ways a lot of people and I really I, I had stress about it. Some of it was artificial because of the environment here." Seemingly following that same train of thought, another associate professor from the life sciences continued, "It's a challenge getting a job that you do have to have single-authored publications…So, splitting the training part from the contribution part I think in the sciences is hard, but the reality is that most, a lot of theses or the papers that come out of it shouldn't have been single-authored."

The struggle between engaging in collaboration with colleagues and establishing a clear independent research career was one that nearly all interviewees discussed. One faculty member in particular talked about her department's critique of her research leading up to tenure as being too collaborative. However, for her collaboration was a means to "jumpstart new directions" in her research and break away from her Ph.D. advisor. This quandary seemed to persist over the course of faculty members' careers. At the associate professor level, a chair of a department in the social sciences cautioned, "In my degree of collaborative approach it's – I had an easy time at tenure, but I would have loved to go up a bit ago for full [professor] and I've been a little hesitant because of that issue of programmatic research. I see connections. I see the point to it all. I think there is actually a single guiding overarching goal that I have, but it's hard to communicate that to folks. So what I, in some respects, what I have to do is even produce more so that the diversity of what I'm producing doesn't work against me."

Another tenure-related theme to emerge from the interviews related to departmental collaboration. A new assistant professor in engineering discussed the importance of engaging more senior departmental colleagues in collaborative research so that they could begin to know his work and serve as his advocate in the tenure process. This was not as simple as it sounded, however. Another assistant professor in engineering explained that new professors are differentially treated by their senior colleagues so that collaborative opportunities within the department are not equally available to all. He explains, "Luckily I signed that [informed consent] form. This [engineering] department is unique. Some [faculty members] are protected species, and there are some that they [senior colleagues] don't want to protect. So apparently I'm outside the protection zone. So these people who are beyond – outside – the protection zone are the people who collaborated more. Those within the shell, collaborate, but within themselves [with senior colleagues in the department]." In other words, this faculty member perceived a degree of favoritism within the department in terms of who his colleagues would collaborate with among the newer departmental faculty. While he would not have been averse to collaborating with senior colleagues within his department, these colleagues were thought to be out of his personal reach.

While collaboration with more senior colleagues in the same department was clearly seen by many as essential to gaining their support in the tenure process, outside collaborations with more renowned scholars were also seen as playing a significant role in the tenure process. A new assistant professor in the life sciences, for example, discussed how collaboration with big names in the field would positively reflect on his research program. In his words, "Okay. So I'm still young faculty, right? And you know I get a bit more beneficial if I collaborate with a big guy in the field. Then they [senior departmental colleagues] think – Oh this young person – oh – he is

able to collaborate with, you know, this people who is very very established and well known in the field. Then he's doing okay." Collaboration as a means of demonstrating affiliation with the leaders of the field was seen as important by many faculty members.

While the affiliation benefits of collaboration within and beyond the home department were articulated by several interviewees, and just as informants spoke to the necessity of collaboration to secure grants and succeed in today's complex scientific environment where the burden of knowledge seems to continue to grow exponentially, several faculty members expressed their frustration with how resilient the old expectations of independently produced research are within the academy. An associate professor in the physical sciences stated it this way, "I work with these teams and so you know it's rare that I'm the first author. There's a student, there's this person, there's whoever [collaborating with me on a project]. There is still this sort of feeling that if you are really worth your mettle you are the driver in all aspects of the research, right? So there is still some cultural [bias], at least in our department…I still get harassed by our P&T [Promotion and Tenure] committee as an associate professor. You don't have enough lead author or senior author papers. And I say, yes I do. My student is first author and I am last author and that means that my student did the research. I funded it and came up with the idea – that's what that means." This speaks to the complexity of the promotion and tenure process, as well as to the on-going challenges presented to faculty members who, after all, are subjected to the subjective interpretations and understandings of their peers in the academy.

A positive development at the university, as articulated by a tenured professor in the social sciences, as well as by an assistant professor in the physical sciences who had just undergone his third-year review, is the explicit incorporation of collaborative research on the evaluation forms used to review faculty performance. "I just underwent my mid-tenure review

this past year and they recently just totally re-did the way that you fill out these forms that you submit," said the assistant professor. He continued, "One thing that you have to include now is that for all papers that you publish, you have to list what your contribution was…That's a direct consequence of the rising number of collaborative projects that people get involved in."

This development seems to be a positive shift, not just for assistant professors, but for associate professors seeking to earn promotion to full professor. For this particular population, collaboration seems to take on a growing role in their research lives, making its explicit recognition an important part of the promotion review process. As one faculty member in the social sciences explained, with tenure faculty members are more comfortable taking bigger risks in their research. This may include taking on more controversial research topics, but it may also include taking on larger collaborative research projects that will take longer to come to fruition. It should also be noted, as it was by several interviewees, that the service commitment of faculty members increases with tenure. This takes time away from teaching and research, and therefore also serves to encourage faculty members to distribute the time burden related to research through collaboration.

The Matthew Effect

In Chapter 2, Robert Merton's notion of the Matthew Effect was mentioned, which refers to the cumulative advantage scholars develop over the course of their careers. Those with established reputations are, all things being equal, able to accrue greater recognition for their work than those who contribute to the same degree but are lesser known. This translates into higher rates of publication, greater impact factors for journal articles, increased likelihood of gaining precious funding for research, and higher citation rates.

Of the 20 faculty members interviewed, 9 made comments that support the notion of a Matthew Effect and made the connection between that effect and their motivations for collaborative research. For many of the faculty members interviewed, the Matthew Effect was considered a leveraging tool to be used. In the very first interview, for example, an associate professor in the social sciences described her shock as an assistant professor when she became an editor for one of her professional journals. She attributed her increased confidence in her own research abilities and her comfort level with seeking out collaborations with renowned scholars in her field to seeing the dismal state of initial submissions made by prolific scholars in her discipline. In her words, "The bravery [to collaborate and send work out to publishers] has come from the fact that I have been on the editor's side. You would be appalled at that stuff I get! You know if a senior member of the field is sending me crap like this – oh you've got to be kidding me, right?! And so in some ways it sort of freed me up. And I also realized how they got to where they were because they send you a piece of crap and you're supposed to fix it **and** you don't get co-authorship! So I was like, oh this is quite the little game. So I was like, we should collaborate more, rather than **me** fix **your** crap. That's really quotable – sorry – I should use bigger words than crap."

This idea of aligning one's research with a respected name in the field also came up in a discussion with a life sciences professor going up for tenure. He explained that as a young faculty member, if the Chancellor or Provost sees that he is collaborating with a "big guy" in the field they are more likely to be impressed and promote him with tenure due to the affiliation, the presumption being that "big guys" don't affiliate themselves with substandard researchers. Interestingly, this also seemed to serve as a deterrent to collaboration. As he explained it, he would like to collaborate with younger peers, but his impression is that none of the young people

want to collaborate with people who aren't "big guys" because it would be seen as a waste of time.

The Matthew Effect was also seen in the actions of some tenured associate professors. A physical scientist, for example, explained how senior colleagues have a responsibility to actively promote the work of their junior colleagues, just as their junior colleagues have a responsibility to promote graduate students. The mechanism for this was to use the senior author's name on a publication to get it out to press, but to affiliate younger and less established colleagues' and students' names with the work to begin establishing their corpus of research and reputation in the field.

An unexpected manifestation of the Matthew Effect came from a social scientist who now works with a federally-funded center on campus. She attributed her prior exclusion from a number of conference panels, collaborative paper invitations, and invitations to contribute chapters to edited volumes to not being formally affiliated with a particular center on campus. The center, in her case, was considered the academic barometer for her area of research. Since she was known to be at the university, but was not listed as an affiliated faculty member on the center's website, colleagues beyond the institution assumed she was either unengaged in her research, or simply producing work of poor quality. Lack of affiliation with a renowned center was a Scarlet Letter. This notion of the Matthew Effect being embodied by an institution was supported by another faculty member from the life sciences who said that a big benefit of joining the faculty of a renowned university is that it attracted good students to help with the research, funding to support that research, and colleagues that can help drive the research forward in innovative directions and help gain recognition for those research accomplishments.

On the recipient end, one well-established associate professor in the social sciences reported that she has been contacted to collaborate on research projects because of her name and the money she could attract, rather than for her intellectual contributions to any particular project. “They needed a big name in the area,” she recalled, “They were doing this research so I came in to help them design the work, but it wasn’t so much an intellectual contribution to the degree that many of my others are.” The funding-related motivations behind such collaborative activity were also made clear by a junior faculty member in the life sciences who explained, “As a junior faculty, it gave me a lot of caché to say that I was collaborating with [name]. Clearly [colleague’s name] lab is very well-funded, and so we wrote a proposal together that did get funded and I got much of the money from that. Um – so I work with [colleague’s name].”

Affiliation with well-known people in the field was seen as an important mechanism for advancement and support in a number of other ways as well. An assistant professor asserted, “The advantage for me is that my collaborations – so, because I came from a very well-known lab as a postdoc, I met a lot of very well-known scientists – now when I email them, they know who I am. In some sense I think ambitiously. Maybe this is ego – I think good people tend to collaborate together. We could both bring something that the other one needs. And so I’ve been very lucky that it has raised my profile a little bit working with very well-known people.” Similarly, this sentiment was shared by a faculty member from the social sciences who recounted his efforts to recruit senior scholars in his field to serve as discussants for an edited volume he had been working on so that their clout and stature would lend weight to the publication at press time.

Intellectual and Logistical Incentives to Collaborate

For all 20 informants, collaboration was seen as critical to securing both logistical and intellectual support. For some faculty members these two seemed to go hand in hand and several interviewees spoke of logistical collaborations evolving into rich intellectual collaborations. For others, however, they chose some collaborative opportunities because of the logistical support they would or could provide, while other opportunities were chosen purely for the intellectual opportunities they would afford.

Illustrative of the dual role international collaborations can play, a social scientist with active collaborations in South Africa spoke of the important logistical role that her affiliate institutions play with regard to serving as a conduit for her field research there. However, she was quick to point out that South Africa has a long and deep academic tradition, especially when it comes to the application of critical theory. In this sense, she felt that she received deep intellectual contributions from her collaborators on the ground there. In her words, "Because I'm working in South Africa, it's a highly developed academic world, you know, that sort of puts ours to shame in some ways. So, I think it has been logistic [collaboration], but they have also been research participants. I'll interview academics, or they will read drafts of my work."

Similarly, a professor in the life sciences explained how his collaborative work is both logistical and intellectual in nature. As his work is more computational or theoretical, he collaborates with colleagues on the experimental side to get a sense of how his models work on the applied side. "I know what I'm doing, and I know what I need from other people to make my research strong," he reported, "So that kind of initiates collaboration. It's a kind of mixture [of intellectual and logistical collaboration]." A faculty member in the physical sciences also spoke of this merging of logistical collaboration and intellectual collaboration when describing the

importance of teaming up with a physical modeler who had a very specific skill set that his lab needed. “He [the physical modeler] really brings a very specific skill set that I don’t have to the table and that adds a lot of value to the what we do in the research,” he said.

While some collaborations were clearly seen as purely technical [logistical], in that the contributors are each contributing their own small piece to the greater project without much involvement at the development or synthesis stages, the two examples just articulated were given by the respective faculty members as evidence of logistical collaborations being combined to create something of unique intellectual merit. As one engineer put it, you can bring together people with a different take on things and their individual findings can be brought, “all together for a bigger goal and bigger analysis [than] we had in the project proposal…”

Some collaborations seemed to have been initiated out of logistical necessity, but became transformed over time to include a strong intellectual component. A life scientist explained that collaborative research that she had engaged in in Vietnam began as logistical because of the site logistics, language barrier, and other challenges associated with setting up field research at a faraway site. This kind of support was often referenced in relation to logistical collaboration. A physical scientist, for example, described her own collaborations with international groups of scientists in her efforts at overcoming the barriers associated with getting all the logistical elements of conducting field work in remote locations worked out. As the life scientist described the transformation of her work on site, however, it became clear that the nature of the collaborative partnership can evolve. In her case, her collaborators soon went beyond just helping to actively participating in all aspects of the research, including the generation of the academic publications resulting from the work.

This idea of logistical collaborations transforming into more robust intellectual collaborations was articulated by many of the faculty members interviewed. As one physical scientist put it, "Sometimes you are making something in a collaboration and it's not a huge intellectual collaboration, just a service…The collaborators do very little in the way of data sharing, intellectual collaboration, engagement. So I see this generally as a waste of my time. The best collaborations are where you have deep intellectual investment and feel that this is my intellectual property." A colleague of this faculty member [from the same department] gave an example of this in action and spoke of how one type of collaboration can lead to the other and develop into a highly rewarding intellectual exchange. In his words, "So really there was kind of a technical question. But then from that once we knew what the structure was I recognized that it could have this kind of reactivity and so they [the collaborators] investigated that and it did and it's just turned into more of an intellectual – I guess maybe what you would call hypothesis-driven [collaboration]."

The last example was a recurring theme in the interviews and speaks to the value of collaboration, as well as to the drive to collaborate with colleagues in the same general field but with differing subspecialties. To illustrate this point, it is instructive to hear how an assistant professor in the life sciences describes the benefits he derives from close collegial collaboration. He stated, "So often we'll have a very specific question that we'll want to get an answer to. It's a case where the question is something that will require some type of experiment that should be standard but is outside our expertise. And so in that sense, we are not asking someone to develop a way of measuring something that they don't know how to do. We are asking someone for something that should be pretty easy for them." In this example, one group has developed the question and made the predictions, while the other group receives an interesting question and

applies their experimental expertise to see what the answer is. The intellectual outcomes are both the answer to the question itself, and the novel application of an experimental methodology.

While many faculty members insisted that it was impossible to separate logistical collaboration from intellectual collaboration since tools, in one form or another, are always essential in completing a particular research project, there was evidence that some faculty members do in fact compartmentalize their logistical and intellectual collaborations and see these as separate and distinct efforts. A good example of this came from a physical scientist who described his own role as a Principal Investigator. In this role, he saw himself as the main collaborator with the primary job of serving as project intellectual. He viewed himself as the originator of a meritorious research idea, the generator of hypotheses, the organizer and monitor of the logistical work of his collaborators, and the person ultimately responsible for synthesizing results and articulating their importance to the field.

A life scientist made a similar distinction, describing the differences he sees between his collaborative relationships with students and postdocs on the one hand, and those he has with faculty member peers on the other. He explained, “The more clear distinction there is for logistics [logistical collaboration] would be kind of under my supervision – if it’s a student or postdoc [where I’m directing the work]. Whereas that wouldn’t be the case for a professor, particularly at another university.” An engineering faculty member referred to this “Principal Investigator-centered” approach as easier to negotiate and often more efficient because roles are highly defined and there is one overarching project goal and leader. A different engineering professor brought some clarity to the remark of his colleague in saying, “If I’m the PI, of course I gonna contribute most to the research. If I’m the co-PI, usually I just provide some knowledge I know. Some do help with the research, but not the leading role.”

Those who described a purely logistical form of collaborative research tended to focus on the technical details of the performance of research. These involved securing funding from granting agencies, gaining access to restricted resources such as databases, and acquiring necessary permits. It was also mentioned by several interviewees who had experience conducting field research abroad, that having in-country collaborators was often necessary in order to acquire governmental research approvals and to meet regulatory mandates.

Several faculty members expressed their frustration with being contacted to serve in purely functional capacities on collaborative research projects, rather than in an intellectual capacity or in a dual capacity in which members of the team are actively working together on all aspects of the research. One faculty member referred to this type of collaboration as more informal "cooperation" in that there is the sharing of facilities and techniques, but little to no involvement on the part of the team in hypothesis generation. In describing one project she lamented, "I just sort of lent – lent a tool and it wasn't necessarily like where we came up with the idea sort of together. This was more me sort of lending some expertise to somebody's project." A different faculty member from the social sciences also spoke of this type of experience and claimed, "Sometimes people will approach me…because they want my tools…But for me personally regarding collaborations, those are not the kinds of collaborations I enter into."

The flip side of the Principal Investigator drawing in different logistical collaborators to accomplish a series of isolated methodological tasks or steps necessary toward answering an overarching research question, is the researcher who sees a technique or method with high promise and develops a collaborative project designed to break new intellectual ground together. A faculty member in the physical sciences described intellectual collaboration by explaining that

while the root activity may have logistical elements to it, there is a shared goal and all collaborators are interested in the same fundamental research question. This is an interesting insight as it draws us away from the notion of defining collaboration according to the types of activities engaged in or according to the nature of the contributions themselves. Rather, it places emphasis on the underlying motivations of the research partners, the overall goal, and the collaborative partners' sense of affiliation with the research goals.

In this sense, within a particular academic department one member could bring a unique theoretical problem to the table based on his expertise and area of subspecialization, while another colleague in the same department could develop the experimental protocol necessary to test the hypothesis generated from the theory using her unique expertise and area of subspecialization. Several examples of this approach have already been articulated in this section. In this type of collaboration, each collaborator brings an independent piece to the table, but they *share the intellectual goal* [emphasis intended] of seeing if the theory adequately predicts an empirical outcome.

Interestingly, it did seem that some faculty members looked to different places to find logistical and intellectual collaborators. An engineering professor asserted that if she were looking for particular skills or a certain technology she would be more likely to look for collaborators on campus because access would be easier and quicker. On the other hand, this same researcher said she looked to national and international collaborations for skills and access to unique equipment as well, but that the focus was often broader in nature and the development of the research idea and the empirical approach to examining a particular research problem was more collaborative in nature. She explained, "I'm looking for people with other skills more on campus, whereas nationally I think I'm looking for people with collaborative **interest** [verbal

emphasis on “interest”].” This sense that intellectual collaboration was driven by shared interest between researchers was a concept articulated differently by the 20 faculty members interviewed, but one that seemed to resonate with nearly everyone. In discussing their underlying motivations for collaborative activity, to a person the interviewees expressed a strong desire to learn something new from collaborative research and a willingness to engage with others in a variety of ways to accomplish that goal.

Idea- and People-Driven Collaboration

Every respondent interviewed discussed the complicated relationship between people-driven collaboration and idea-driven collaboration. Some saw these as separate and distinct mechanisms for bringing about collaborative research, while others saw these two approaches to collaboration as inseparably linked. The concept of idea-driven versus people-drive collaboration was brought up in the very first interview with an associate professor in the social sciences. When asked how she picks her collaborators, this faculty member said, “I don’t know if it’s been deliberate. I mean, I guess it’s been. Sometimes they are idea-driven and sometimes they are people-driven, if that makes any sense.” She went on to explain that some projects have emerged because of the people she became involved with. Serving on panels, for example, were articulated as opportunities to get to know another scholar’s research, develop trust and respect, and explore possible opportunities for future collaborative projects. These types of collaboration could be seen as convenience-related. People with similar interests become aware of each other, grow to respect and like each other, and find ways to bring their research together for a collaborative project. The main draw is the human dynamic and the opportunity to work with another scholar on a new project, rather than a set of research questions.

On the other hand, idea-driven collaboration was articulated as more idea- or research-question centered. In this scenario, a faculty member develops a new research project first. The topic takes precedence. The idea may be the result of a call for proposals from a funding agency, an article read in a journal, a workshop participated in, or a poster session attended at a conference. The key point, however, is that the collaboration starts with the emergence of a research idea within an individual. That researcher then pulls in the collaborators needed to accomplish the goals of the project.

While this social scientist treated these concepts as dichotomous, most of the other interviewees spoke of an interaction between the people on a collaborative project and the power of the idea that brought people together in the first place. In the words of an engineering professor, " I would think that each collaboration is a combination of idea-driven and also people-driven. We need to have the right chemistry between the two collaborating people, and the base should be a solid idea." Similarly, a social scientist asserted, "Even if **you** are just purely driven by the idea, you know not everyone else who you wanna draw into this project is the same idea-driven. So that's why I'm saying that almost immediately that idea-driven project becomes people-driven."

Achieving a state of equilibrium between the inherent difficulties associated with working with other people and the power of working on an idea that is compelling to all collaborators was clearly a complex process. For example, a physical scientist discussed how interpersonal difficulties can be worth overcoming when the collaborator adds valuable skills to a project. He described a current collaboration this way, "He's a good collaborator scientifically [but] we sort of struggle sometimes just from a personality point of view. But, he really brings a very specific skill set that I don't have to the table that adds a lot of value to what we do in the

research." This statement shows how a good idea can drive collaborative research and create a certain level of immunity or relative indifference to challenging interpersonal dynamics. Indeed, a life scientist was quoted as saying, "Collaborations happen most naturally when the different people involved can't do one part or the other, alright? So you are kind of forced to wait on the other person to deliver."

Admittedly, however, this is not always the case and science, or the power of the idea, is not always able to compensate for difficult interpersonal dynamics. One physical scientist spoke of a project that he became interested in initially because of the science. However, the program had become so large and so complex due to all the stakeholders, that the negative personal experiences were beginning to outweigh the compelling nature of the science. In his words, "I think one of the potential issues with non-organic forms of collaboration [idea-driven], which sometimes happens inside the university, you know, intra-university [is that] I think that you have a higher probability of having to interact with personalities that are disparate from yours And without really strong leadership, I think the productivity side of things can go down pretty significantly."

This faculty member, as well as several others, emphasized that large projects requiring many collaborators will almost inevitably result in interpersonal tension. In the words of one social scientist, "Honestly, I think any idea-driven collaboration almost immediately becomes people-driven." The potential for negative interpersonal dynamics was considered by many as a cost of doing good scholarship. To quote the physical scientist again, "I have a standard rule that I don't like to work with people who are toxic…because that just takes a lot of energy to deal with that sort of stuff. But, I do have a couple projects now which are so large that it's sort of

hard to not have at least one person who is difficult involved and I'm trying to get my head around making sure that I meet my goals for the deliverables."

Several faculty members articulated a very utilitarian approach to choosing collaborators. In addition to choosing collaborators because of their ability to contribute a critical piece to a good idea or their compatible personalities, may faculty members reported taking into account colleagues' work ethic, the impact that involvement in a collaboration would have on their resume, or the effect that a successful outcome might have on tenure. In the words of a pre-tenure social scientist, "In my case it [choosing collaborators] was all largely driven by, you know, I liked the idea or I liked the person who suggested the idea, or I thought that I just should do it because it's gonna benefit me, my resume, my, you know, prospects for tenure…It has largely been driven by this kind of utilitarian logic." This statement shows the complex set of factors that go into the process of deciding whether or not to engage in a collaborative research project.

Nearly all those who articulated a bias in favor of choosing collaborators because of the people who would be involved, were relatively new assistant professors at the university. This is not to say that others didn't feel that the interpersonal dynamics played an important role in collaborative research, but for most people there was more of a balance between excitement to collaborate with certain people and the excitement of collaborating on a particular project because of the power of the idea. However, for those who did seem to favor collaborations with those that they had stronger personal relationships with, time in the field and culture seemed to play a major role. A first-year Chinese faculty member in the social sciences, for example, explained that she had collaborators in China because it was important to her to maintain those ties to friends from her home country. This same faculty member also spoke of her

collaborations with her former Ph.D. advisor, reinforcing the notion that newer faculty members maintain ties to their Ph.D. and postdoctoral mentors as they establish themselves in their new careers.

Another assistant professor, a faculty member in the physical sciences, also spoke of a strong bias toward choosing collaborative projects based on the people involved. She said, "I think 95% of the collaborations that I've been involved with have been the latter [people-driven]. It's the people. You are like – hey – and then you chat about ideas and you come up with ideas. [But] it's rare that you are kind of – this is the skill that I need, who can I farm – who can I – you know – bring into that project?"

That being said, this same faculty member did emphasize that much research collaboration is "opportunistic." She explained that you never know when you will be talking with someone and a good idea will come your way. Engagement in collaborative research with that person may be due to the availability of grant funding, or simply a desire to help out a colleague in need. A perfect example of this came out in the last interview with an associate professor in the social sciences. He explained, "I've had a couple of collaborative projects that started out as somebody else's paper…They are almost always someone that I'm friends with. [They say] can you help me out, right? So that's a situation where the paper is already becoming an article, but it had already started before I was even on board. So that's a case where I have to fit within their sort of overarching theme and kind of you know – transform whatever I'm thinking into how they wanted to think about the project and add a little bit to it sort of as a complement."

These last two examples show how quickly the line between people-centered and idea-centered collaboration can become blurred. If one maintains connections with a colleague and

keeps in regular communication, is the collaboration to emerge upon a new grant opportunity driven by the personal connections or the power of their collective ideas? A physical scientist put it well when she said, “Both of those things are going on. I think that I fall more towards the personal interaction end of things, you know. [But] I certainly don’t think I collaborate with people who are poor at what they do by any stretch.”

While the inter-personal dynamics are clearly important, and everyone seemed to agree that collaborative research is more efficient, more rewarding, and more likely to be successful when there is a positive rapport and trust between the project stakeholders, it must be said that many spoke of the power of a good idea to draw them into a project. One life scientist described contacting colleagues because he wanted to have access to a particular molecule that could be evaluated using a novel protocol that he had developed and really wanted to test. This same faculty member spoke to his previous efforts to build collaborative teams based on people that would bring unique strengths to a particular project he felt strongly about. Both cases indicated a desire to bring in people to accomplish a goal-oriented project.

Hard Currency Gains from Collaboration

Experienced gains from collaboration ranged from the highly concrete to the more intangible. On the concrete side, what one faculty member referred to as the “hard currency” of collaboration, faculty members had collaborated in order to generate co-authored publications, capitalize upon on or gain access to scarce resources, or establish new research programs that might lead to successful collaborative proposals for funding. When exploring these tangible outcomes from collaborative research, it was somewhat surprising that only 5 out of the 20 interviewees brought up publications as a specific outcome experienced. Three of these

interviewees were at the assistant professor level and while three of the interviewees were in the physical sciences, the life sciences and engineering were also represented in this group. In other words, there were no clear patterns with regard to the focus on publications as an outcome by such factors as faculty rank or field. However, 4 of the 5 who indicated that a major focus of their collaborative efforts was to generate co-authored publications were male.

Gains experienced through the sharing of scarce or unique resources were probably the most commonly articulated tangible outcomes that interviewees had experienced. These gains ranged from the sharing of timesaving lab protocols, skills, tests, and techniques, to the actual exchange of equipment, labs, molecules, and even students. As one faculty member in the physical sciences put it, "We use their [colleagues'] laboratories, our students take their classes, there is a lot of swapping of analytical techniques, and students go back and forth. Samples are being run sort of one place or the other." These hard currency exchanges were mentioned by faculty members across fields and genders, as well as across both ranks.

The final dominant hard research currency mentioned in the interviews was currency itself. Several faculty members spoke of how their collaborative efforts yielded tangible results in the form of external grants to support their research. Indirectly, for example, the collaboration may have yielded a needed letter of institutional support for a research proposal, as was mentioned by one life scientist. It was also mentioned that the names on a joint proposal may have simply added credibility to it in the eyes of a review committee. In the words of an assistant professor in the life sciences, "Having a paper together with your collaborator – name only – that has a benefit and [sends] a clear message to your grant proposal reviewers that I'm not – you know – lying [about the fact that I can do this]!"

Naturally, external funding was considered critical to establishing a sustainable research program. It is also important to be aware, however, that in the eyes of many researchers, collaboration is not the end goal, but rather a means to achieving a higher order goal such as funding for research. Letters and proposal clout are welcome intermediate gains from the collaborative process, but in the absence of funding as the ultimate outcome prior to the commencement of the research itself, collaboration can quickly fall apart. An engineering professor explained it this way, "Well certainly collaboration in preparing proposals you know, if it doesn't get funded it's hard to keep the project going. So until the project gets, you know [going], the collaboration tends to be you know, just helping write the proposal until you get funding. At which point it becomes a much more dynamic collaboration typically." This speaks to the differing levels of collaborative activity and how funding can move a collaboration from a relatively low or peripheral level to more intense intellectual engagement leading to academic production.

Soft Currency Gains from Collaboration

On the "soft currency" side, gains from collaboration were much less tangible, but equally, if not more, rewarding. An associate professor from the social sciences described it this way, "What are the products of these collaborative processes? We don't have a paper. There was no grant. [But] I still would characterize it as a fruitful collaboration. The knowledge gained, the things that they [collaborators] can add…" This was the overwhelming sentiment among the researchers interviewed and many simply articulated the joy they experienced in learning new things from a collaborator, in discovering a new concept or phenomenon, or in the camaraderie associated with the process of working out new research ideas. As a new professor in the life

sciences put it, “I view collaboration in the sense that, you know, you put your knowledge in, but at the same time you wanna learn things from that other side, right? Things start from the negative side and [you] argue. Through the argument you may know the person better, right? That may turn out to be a good collaboration.”

Collaboration was seen as a mechanism for bringing new knowledge into a research group or project through informal hallway or coffee shop conversations, as well as through more formal partnerships. This knowledge was not necessarily for a specific purpose or a specific research project currently underway, but often served as intellectual capital to engage with and that might bring added insight into research problems. One researcher pointed out that collaboration was a means for learning more about colleagues’ work, sort of a networking outcome. This was seen as helpful in choosing future projects in that it was easier to assemble a collaborative team when all the possible contributors’ areas of expertise are known and the potential could be seen.

An excellent example of these perceived outcomes is described by an assistant professor in the social sciences who discussed the role that she would like her senior colleagues to play in terms of generating positive outcomes through collaboration with her. In her interview she explained, “I have to be called to take part. I have to be introduced to the possibility of collaboration by somebody else…There is this more senior figure with more experience, with more networking, with more publications, but who wants to do this project and sees that I can benefit the project. And this person inspired me, this person generates ideas, listens to me, directs me. I learn from, you know, this person and the process of collaboration.”

This last quote really captures the larger and more lasting gains that many faculty members felt that they get from their collaborative activities. However, as was discussed in the

section on tenure and collaboration, many faculty members were wary of too much collaboration, despite all of the potential positive outcomes. There was also concern among several interviewees that collaboration can lead to unhealthy dependencies upon others and either slow down or harm the overall research objectives of faculty members. As one life scientist put it, "I moved away from collaborations and thought, I have to have a way not to [collaborate]. Collaborations are great it they bring ability to do new things. But we can't be totally dependent on them."

Tangible Forms of Reciprocity

Faculty members' expectations of reciprocity when engaging in collaborative research ranged from the highly practical to the more intangible. On the practical side, respondents discussed the need to have two-way communication between researchers. This was seen as important for a number of reasons. First of all, as an engineering professor put it, two-way communication is critical if researchers from different disciplines and contexts are to develop an understanding of each other's field-specific languages. "Collaboration is two-way communication," he said, "From management point of view, when we start collaboration, both sides need to invest a certain amount of time and resource [to] learn the [disciplinary] language that other people [are] speaking."

Establishing this open communication pathway was also seen as critical to the development of "shared responsibility for the quality and quantity" of the research, "shared vision and goals," as well as for the attribution of credit when the work was completed. The faculty members interviewed did this in a variety of ways. Some took a very proactive and hands-on approach in that they worked out project roles for all participants and developed an

understanding of who would get authorship on project outcomes prior to the commencement of research. In the words of a life scientist at the university, if you know "what's expected of everybody…from the get-go [it] makes it easier." As an example of this in action, an engineering professor discussed how he had developed a written contract for his collaborations to ensure clarity with regard to responsibilities among the participants and ownership over results.

Authorship itself played a central role for many of the researchers, and this was a trend that spanned the disciplines, ranks, genders, and citizenship statuses. A social scientist, for example, explained that, "Effort in a collaboration, in terms of reciprocity, is largely dependent on authorship. If she is the primary author, she sees her role as bigger." Agreeing with this, an associate professor in engineering stated, "Collaboration does relate to authorship. Who gets author has to be somebody that's contributing. I mean there is everything from token collaboration where they are just kinda involved and occasionally give a comment…to you know full-fledged in the trenches."

Authorship was also seen as a form of compensation for collaborators, and something to be used in the negotiation process. A life scientist explained, "How do you reward somebody for basically taking on that risk of synthesizing a molecule? Well, if you didn't have that molecule you wouldn't be able to run the tests that you specifically wanted to in the first place when you contacted me. So a nice way to sort of meet in the middle for my expense…[is a] joint publication." A social scientist seemed to share this sentiment, and added that by sharing credit for the work a more equitable division of labor can be achieved where no single researcher is left doing everything alone. With authorship, in other words, comes a commitment to contribute and an opportunity to negotiate forms and levels of contribution.

It must be emphasized that authorship was not universally seen as an indication of reciprocal contribution. Earlier, the concept of "token" collaboration was mentioned, in which a person gains authorship on a paper even though they didn't contribute substantially to the project in any way. A professor in the physical sciences hinted at how this might come about when she said, "I can be a co-author on a paper and not have met a number of the people on that paper, you know? And I know like 80% of them [the co-authors] haven't even read the paper that they are on…"

This type of arrangement can come about in a number of ways. One professor in the physical sciences discussed how she uses authorship to acknowledge facility directors that have provided access to key equipment for a research project. This same faculty member also discussed the pressure to include people's names as coauthors, not because of their contribution to a particular project, but because of the anticipated contribution that had been agreed upon and a shared understanding [developed in advance] of how authorship would be shared. Even when the colleague's contribution was reneged upon, this faculty member expressed how hard it is to rescind an authorship agreement and how avoiding conflict is often the easier route to take. In her words, "We've had issues where I've been the lead author where I basically didn't want to put somebody on because I didn't feel like they contributed, and my colleagues said, well we decided everybody is going to be on every paper. I always try to err on the side of you know…I'm just going to do it because in the end it's really no skin off my back."

While communication seemed essential in the eyes of most of the researchers interviewed, especially for assigning work and determining authorship, for others there seemed to be a set of assumed universal principles with regard to collaborative research that were considered common sense, and therefore did not need to be actively communicated to partners.

For example, a life scientist described the rules for the attribution for research quite simply when she said, “The person who writes it [up] gets their name on first and you know, I don’t think it’s ever really been an issue.” A different faculty member in the life sciences felt that authorship should be decided based on the “level of intellectual contributions” each participant had made. Yet another group of people felt that a person’s status as the Principal Investigator gave them the right to assert their first author rights because they were thought to be the drivers of the idea and were the key resource people involved, since the PI’s role is make sure everything is done right.

Intangible Forms of Reciprocity

On the more intangible side of reciprocity in collaborative research, lies the mutually understood value of the research, as well as trust. With regard to value, the main theme to emerge was the sense that research collaborations were only as valuable as the degree to which they enhanced the research itself or brought a new perspective into the mix. In other words, collaboration was seen to play a highly functional role and was not, generally, done simply for the sake of collaboration itself. That being said, many faculty members did comment on how much enjoyment they got out of collaborating with others. A life scientist talked to the value of collaborative research in this way, “You put your knowledge in [to the collaboration], but at the same time you wanna learn things from that other side, right?” Similarly, another faculty said, “I would be looking for somebody who has a different perspective on it. Who can have a fresh set of eyes. It’s an ideal scenario – it’s also the shared workload.” Other interviewees chimed in as well and talked about the degree to which collaboration helped broaden their perspectives.

Many faculty members spoke to a personal sense of responsibility in terms of bringing value to the collaboration in the form of time, passion, effort, and new ideas. When this cannot

be done, many indicated that they would not engage in collaborations. In the words of an engineer, “If I feel that I cannot contribute at all, then of course I say I can’t contribute.” The contribution of time, ideas, energy, and passion, however, are generally discussed within the context of the mutual benefits to be derived. A natural scientist articulated this balance well when he said, “My willingness to engage with inquirers depends on whether the project engages me intellectually. How open and receptive and mutually beneficial will the collaboration be?”

Faculty members’ general sense of the importance of mutual benefit in collaborative research [wanting to give to something, as well as to receive a benefit from it], is not to say that they are seeking an absolute balance in contributions. Indeed, the comparative contributions were seen to be highly fluid over time, and many faculty members emphasized how collaborative activity and level of contribution must be viewed over time. When asked about how he establishes reciprocity in a collaboration, a new professor in the life sciences said, “It’s not - you see you can’t really. For example, I give them ten [somethings], right? And I only got 5 [somethings in return]. This is not a good collaboration. You don’t view the collaboration in that way. It’s more desirable to have a long-term collaboration so that sometimes you may give more or you know you sometimes gamble… You lose before you start if you start thinking about it that way [that balance is important].”

While most interviewees did not place a great deal of importance on maintaining a constant balance in terms of the value of the contributions brought to the table by each partner in the collaboration, what was resoundingly clear was how essential a strong sense of reciprocal trust was within this group. For example, some faculty members spoke of the importance of believing in a colleague’s work ethic before engaging in collaborative work. As was noted earlier, this was seen as especially critical on funded projects where distribution of work was

essential to timely completion, while the Principal Investigator was largely responsible for ensuring that the work was done on time and to the agency's expectations. Failure was not seen as an option given the adverse effect it would have on the faculty member's ability to acquire external funding in the future. Risk averse researchers, therefore are not going to engage in high-stakes collaborative research unless they know they can depend on their colleagues to live up to their end of the bargain. Trust was a deeply personal issue, with many of those interviewed feeling that a colleague's personal investment in and commitment to a project was even more important than the level of the contribution made. As the quote in the preceding paragraph makes clear, people are willing to give their colleagues some slack in the near term if the longer-term prospects of a productive collaboration are considered strong. Overall, authenticity and the belief in a mutual sense of commitment were critical considerations for those interviewed.

Collaborative Skill Development

Addressing the third qualitative research question, "What is the perceived relationship between the collaborative work done in graduate school, the postdoctoral research period, and the respondents' faculty careers?" this section develops a grounded understanding of how faculty members feel they developed their collaborative research skills. After a brief review of interviewees' first reported collaborative research experiences, the role of respondents' academic and postdoctoral training will be explored. Special attention will be given to the role of researchers' training at the undergraduate, graduate, and postdoctoral levels, the role of institutional structures in the fostering and development of collaborative skills and finally, the impact of mentoring received from colleagues on the faculty. While undergraduate training was not initially part of the research question on the development of collaborative skills, its recurring

inclusion as an important developmental period for the faculty members interviewed demanded its inclusion.

First Collaborative Research Experiences

A portion of each interview was devoted to a discussion on how faculty members developed their collaborative research skills. As summary Table 5.1 showed 8 faculty members indicated that their first collaborative research experience was at the undergraduate level, 11 indicated that this experience occurred during graduate study, and only one faculty member indicated that her first collaborative research experience was prior to her undergraduate career. As these overall numbers indicate, every faculty member interviewed had a collaborative research experience prior to beginning his or her faculty career. Furthermore, for the 15 informants who had completed a postdoctoral research experience, all had at least one prior collaborative research experience.

For those who indicated that their first collaborative research experience was during their undergraduate years, a variety of experience types were articulated. One of the social scientists, for example, got her first taste of international field research by serving as a research assistant for one of her professors on a trip to Africa. She recounts, “It’s not like I was a co-author, but that project wouldn’t have happened without me and so it was at that moment that I realized you can get more done as a team than you can as an individual.”

For the others, their undergraduate collaborative work experiences mainly involved working in laboratories under direct faculty supervision. Among faculty members in the physical sciences, engineering, and life sciences [none were social scientists], some reported serving on multinational teams with faculty members, postdocs, and graduate students. Others worked

directly with an individual faculty member on a research project or a Bachelor's thesis. One faculty member from the physical sciences reported a succession of undergraduate research experiences that really cemented her passion for science and research. She began working at a national lab with a variety of researchers in her capacity as an assistant running samples on a specialized piece of equipment. She was then selected by a foundation to join a group of college juniors from a consortium of colleges and universities to conduct collaborative research with her peers under the supervision of a couple faculty members. Finally, these experiences leveraged her a position as a lab technician with one of her professors from her undergraduate program.

The majority of those interviewed reported their first collaborative research experience at the Masters or Ph.D. level. Three of the 11 were faculty members from the social sciences, 3 were from engineering, 3 were from the life sciences, and 2 were from the physical sciences. One of the social scientists who reported a first research collaboration during her graduate years was a faculty member who had taken a course on experimental design. After the course had ended, she collaborated with her research partner, another graduate student, to publish their first paper together. This was one of only two examples given of peer-to-peer collaboration at the graduate level. The other example was offered by a different social scientist who had also worked on co-authoring a paper with a colleague from his program.

Among the remaining group of faculty members who reported an initial collaborative research experience in graduate school, most reported working as researchers on larger teams comprised of other graduate students, postdoctoral researchers, and faculty members. Two interviewees, however, one in the social sciences and one in the life sciences, had worked one-on-one with a faculty member on field research and had become co-authors on resulting publications. There were also a few anomalies among those interviewed. One engineering

professor, for example, had completed an internship at a national laboratory where he had the opportunity to work collaboratively with a large group of people. Another engineering professor recounted how her Ph.D. advisor had connected her with a visiting speaker on campus, which had led to her first research inter-institutional collaboration. Finally, a faculty member from the physical sciences described how he had become part of a multi-institutional research team during his graduate program.

The remainder of this section will examine the perceived role these experiences had in respondents' development as collaborative researchers. How faculty members rank ordered the impact of their overall experiences prior to beginning their faculty careers, including their postdoctoral research experiences, will also be explored. Finally, perceived gaps in people's training will be discussed briefly, along with the mechanisms interviewees had employed as faculty members to close these gaps.

The Role of Undergraduate Training

In discussing the impact of their undergraduate research experiences, two highly related themes emerged. The first of these was the concept of connections spanning academic departments. As one life scientist put it, "I learned that things are connected and [that] these artificial silos associated with departments are really artificial. There are people who are better chemists in the geology department than the chemistry department. People in the Geology department who could easily be called biologists." This remark shows an understanding shared by many of those interviewed and speaks to why many faculty members indicated strong and mutually beneficial connections at the intra-departmental level. There are not only people across

departments with shared training and fundamental understandings, but there are research questions that simply demand the informed merging of different academic schools of thought.

The second related theme to emerge was the idea that depth of specialization within a particular discipline has its limitations. A life scientist described it this way, "I was an undergrad…and you know we had it [lab] set up as a shop. We sort of did everything in-house…So I did a very much chemistry-centric type of undergraduate research experience. And so there wasn't really any applied method." He went on to explain that because of the isolation he had experienced as an undergraduate due to the depth of specialization, he had felt the need during his doctoral work and postdoctoral research to delve into that "applied" side of chemistry so as to get to the point of seeing what the molecules he had created actually do.

This latter experience speaks, to some extent, to the theme that many interviewees articulated in terms of why they collaborate at the departmental level. Bridging the divide between the theoretical and the experimental can give one a sense of completion on a project, and the merging of the two areas of specialization within a particular discipline serves to enhance the opportunities and experiences for both sides. This was summed up well by another life scientist who spoke about why he collaborates with experimentalists within his department. In his words, "I mean, we all have strategies for our labs and I mean you have to have a motivation for taking on any project that you are going to [do], and I don't think mine are any more self-serving than most. I mean they should be – they have to be self-serving. But really, I think all collaborations in my lab stem from that [undergraduate] experience. Because in all cases we are doing our thing, [and] our thing is going to be fine without you. But value would be added if you want to help. And those are the types of collaboration that I've really pursued because those are the only ones I feel quite comfortable with."

Both of the general themes discussed above represent life-long lessoned learned from faculty members' undergraduate careers. These experiences and the realizations that emerged from them, significantly affected their decision-making related to the choice of graduate or postdoctoral research program, and still affect the way that they collaborate as faculty members. We now turn to the role of graduate training in the development of collaborative research skills.

The Role of Graduate Training

Graduate training was seen as enormously impactful by nearly all interviewees with regard to the development of collaborative research skills. For some, graduate school served to introduce and reinforce the importance of collaborative research directly. For others, as was the case for both undergraduates in the life sciences referenced above, graduate school served as negative reinforcement in that they found their experiences so limiting or so isolating that they dedicated themselves to a more collaborative approach in their future careers.

Many reported that graduate school was a time in which collaboration was extremely difficult. Even in departments where faculty members were clearly working collaboratively, doctoral students were encouraged to work independently, to be "self-reliant" as one physical scientist put it. A social scientist explained, "I think my graduate training is um a little bit of an irony or an enigma or something. [My school was] deeply interdisciplinary…Departments didn't even have offices next to each other. People moved offices based on research projects. So, if you were working on migration, people literally packed up and moved their offices and had offices on one floor for three years…[My] department [though] trained us to be entrepreneurs because they said you're gonna have to stand on your own two feet when you are out there so let's see if

you can do it now. So it was an irony because they beat it [collaboration] into us and yet I didn't actually have any goods [collaborative experiences], you know."

Several other faculty members spoke of their graduate programs' emphasis on developing them as independent scholars. A life scientist recalled that his doctoral program advisor's "stated theory of graduate education was to throw them in the ocean and see if they can swim. He saw it as a hindrance that he would be too directly involved." Another life scientist described how he was left on his own to do his dissertation research, only to be told that the corresponding senior author on the resulting publication would be his doctoral advisor, even though he felt that his advisor had not helped him at all along the way. It should be noted, however, that this negative sentiment was only articulated by one interviewee. It was far more common for respondents to talk favorably about the one-on-one collaborative experience that they had with their doctoral program advisor and the active mentoring that they had received. A social scientist summed it up this way, "You're a grad student [and] you collaborate with a professor. You do the data analysis and they do the write-up, or vice versa. And you get credit for it, which is great. Actually, for…a lot of my graduate colleagues at my institution, that was how it was. And it simulated to some degree what that version of social science was supposed to be."

While it was clear that some felt their graduate advisors had been unhelpful when it came to fostering the development of collaborative research skills, others found their advisors to be absolutely instrumental in their indoctrination into the realm of collaborative research. One associate professor in the life sciences, who still maintains an active research collaboration with her doctoral program advisor, discussed how her advisor had worked hard to integrate her into the scientific community and bring her into her own network of scholars. Many faculty members who reported maintaining collaborations with their graduate mentors spoke of how these mentors

actively worked to bring them into their larger scientific networks. The broader network of ties that seemed to get established at that time seemed to serve a dual purpose in that they connected the Ph.D. students with a broader community of collaborators, while reinforcing the mentor-mentee relationship as it evolved into a relationship between peers.

A key mechanism for being brought into that broader network of collaborators was conference attendance. While some discussed attending conferences on their own and meeting other graduate students who would later become collaborators at other institutions, others spoke of how their advisors had carefully included them at conferences, helping them to expand their knowledge networks in more deliberate ways. Relating her own experience with this, a physical scientist recalled, "I'm really grateful to my Ph.D. advisor for bringing me along to a lot of conferences when I was a student, and also my Masters advisors, because you know it really allowed me to meet those key players early on so that, you know, ten years from [that time] I feel like I know them well."

It was also clear that many faculty members learned about the power of collaborative research from their mentors' modeling behavior. This took on a number of forms. For some, it was becoming part of a larger research team under the direction of a faculty mentor. In the words of one physical scientist, she "saw the network in action" and became a part of it. This reinforced the importance of exposing doctoral students to larger collaborative research projects involving multiple faculty members, graduate students, and postdocs. For others, observing a mentor's decision-making with regard to how and when to collaborate in research was informative. In terms of when, some faculty members recalled learning how collaborating with colleagues at other institutions was critical to securing grant funds. Others emphasized learning about the

importance of collaboration to gain access to key equipment or necessary materials for an experiment [lab samples, for example].

In terms of how to collaborate, several faculty members spoke of the cultural knowledge they had gained by serving on large and diverse teams as graduate students. An associate professor in the life sciences explained, "We used to laugh because you know we more or less had the United Nations in the group we worked with because we had people from…Italy, we have people from Ukraine, we have people from Poland, from Russia, we have people from China, Korea, Japan. So with all of those, you just get a sense of, you know, you get a sense of how people are. And India I should mention as well. But you know how you can collaborate with people and learn differences in cultures in terms obviously good and bad…You know [you are] getting a sense of what's [who's] out there."

For a small portion of those interviewed, graduate school was not enough in terms of the training needed to collaborate effectively. Three faculty members, for example, spoke of the limited collaboration that they had been able to engage in as graduate students and how this had caused them to pursue postdoctoral research opportunities in the U.S. so that they could gain that experience and begin expanding their research networks. That being said, others pursued postdoctoral research opportunities for the opposite reasons. One faculty member, for example, spoke of an intensely negative collaborative experience he had in graduate school. He had been reliant upon a postdoctoral researcher to run some tests for him with highly specialized equipment residing in another lab. The results of these tests were critical to his research, but the postdoc was absolutely unwilling to work with him, despite a request from the postdoc's direct mentor. The outcome of the research was ultimately unsuccessful because of the missing pieces and the graduate student's inability to get the postdoctoral researcher to work with him.

The decision to pursue his own postdoctoral research experience was an overt effort to learn about a different set of technical skills so that he would never be wholly dependent upon another researcher for the successful conclusion of his research again. While many recognize that the increasing burden of knowledge virtually necessitates collaboration at some level, and others made it clear that collaboration is advisable in situations where someone's depth of expertise in a complementary area can really enhance the overall project, many noted, "How limiting it can be when your group is completely dependent on collaborators." The next section discusses the perceived role of the postdoctoral research experience in the development of collaborative research skills.

The Role of the Postdoctoral Research Experience

While many interviewees felt that their postdoctoral research experience had been helpful to them in the development of their collaboration skills, some respondents expressed frustration with the lack of acknowledgement that they had received for their contributions. One researcher in the life sciences described it this way, "Any individual you hire you wish them to be creative, and maybe you [the Principal Investigator] get a different direction of research out of that [creativity], right? But still, you [are the one] pay[ing] them, so…their product is yours. So in our field, I developed something during my postdoc…I did everything. Everything was my idea, and I did that and people know in the field that I did it. But when I wrote my first NSF proposal…one of the reviewer[s] say, this is not your method, this is your postdoc mentor's method. So I have a group here [at the university], right? Their product is mine [now], not theirs."

On the one hand this passage shows how complicated attribution can become for original scientific work. In the case above, the PI earned a grant that enabled him to hire a postdoc. That postdoc then produced original work and, at one level, was recognized for that work by members of his field. However, in the grant world, the agency only recognized the PI for the project outcomes, in effect making it difficult for the postdoctoral researcher to acquire future funding as an independent researcher to capitalize upon his or her past research successes. On the other hand, the shadow collaboration that this person had engaged in as a postdoctoral researcher, taught him in turn to engage in that same pattern of collaborative activity as an independent researcher by taking ownership over the accomplishments of the team that he had assembled and supported through his grants.

Shadow collaboration aside, the overwhelming majority of those faculty members who had a postdoctoral research experience reported very positive outcomes. This is not to say that those outcomes came without stress, however. A physical scientist, for example, explained that as a postdoctoral scholar his supervisor had been so busy that he "ended up doing a lot of work that an assistant professor would do." By being the "go-to" person in the lab, he learned how to bring in other people strategically to keep the research moving forward.

The postdoctoral research experience was considered by most to be a unique time in their professional lives to focus entirely on research and engage with others in the performance of that research. Looking back, this was seen as an exciting and inspiring time where research roots were established, interests and skills were honed, and critical connections were made. As one life scientist put it, "The environment, as in the physical as well as the people, instills collaboration because it's such an awe inspiring place [location of her postdoctoral research appointment]."

In terms of the establishment of research roots, the postdoctoral research period was the first time that many faculty members had a chance to focus on their research and develop research relationships with colleagues. An engineering professor spoke of her postdoctoral experience as being the first time she had an opportunity to work in a smaller lab. This afforded her the opportunity to work on multiple levels of a particular project, but also the chance to work more intensively with a dedicated group of people. A life scientist put it well in describing his own experience, "My postdoctoral mentor [said] if we are going to go after this particular project, you need to call this guy…So the logistics of how to do that was more of a mentorship that I got from my postdoc mentor." In other words, many faculty members were mentored in the art of engaging others in their research to accomplish project goals during their time as postdoctoral researchers.

Ironically, while some faculty members reported that serving as a postdoc in a small lab afforded them more opportunities to engage in collaborative research, some faculty members said the same thing about serving as postdocs in larger labs. A life scientist, for example, discussed how his postdoctoral lab was so big and compartmentalized, that his mentor frequently advised him to contact outside colleagues to lend their specific expertise to the pieces of the project he had been working on. In this case, the size and busyness of the lab resulted in lack of access to the mentor and the mentor's skills. This necessitated reaching out to others beyond to immediate team.

In terms of interests and skills, several interviewees spoke of their postdoctoral research time as absolutely critical. A professor in the life sciences, for example, spoke of how he had learned about the reciprocal benefits of sharing research findings openly with colleagues during his postdoctoral years. In his words, "I don't feel scared or nervous in any way having

collaborations. I guess in principle I understand why it could be an issue. But a lot of the philosophy came from my postdoc mentor who would have people [over who] I consider competitors, because they were working on exactly the thing that I was working on as a postdoc. He would invite them into our lab and he would tell them exactly what I was doing and my clever insights. And I would sit there thinking, what are you doing?! You are giving away all our secrets! But he was just such an open sharing type of scientist that what ended up happening is that people would notice things that we weren't doing that we could be doing better even though they were competitors and inevitable they would tell him, and our research would get better. And so he had such an open sharing attitude, and eventually I saw the benefit that he was deriving from it, so I sort of adopted that for my lab as well." This is a perfect description of the type of collaborative attitude that many faculty members derived from their postdoctoral mentors. This was not an explicit lesson in collaboration, but a skill learned on a much more tacit level.

With regard to the skills learned from the postdoctoral experience, several interviewees spoke of using their postdoctoral research time to learn a new skill to enable them to become more independent researchers. While it may seem ironic to collaborate with someone to develop independence, as was explained in the previous section, negative experiences associated with having too much reliance on a research collaborator were major motivators in this regard. As one physical scientist put it, "When I was a postdoc I went to work for a group that was more synthetic – more making molecules, because I saw that one of the downfalls of having collaborations is that sometimes you are just sitting there doing nothing, cause you are waiting for people to send you stuff."

In terms of making connections, the postdoctoral research experience was seen as absolutely essential by many faculty members. Nearly all faculty members who had completed a

postdoctoral appointment, for example, still maintained research collaborations with their former mentors. In addition, connections were often maintained with those who interviewees had established collaborations with during their postdoctoral years. A life scientist described maintaining collaborations with many of the researchers who had come through his postdoctoral mentor's lab during his time there. Similarly, institutional connections established during the postdoctoral years were often maintained by faculty members as they began their independent research careers.

The postdoctoral experience was seen as a time to build critical long-term connections with institutions supporting and colleagues engaging in research related to their interests. By way of example, a faculty member in the life sciences chose his postdoctoral research experience not because he wanted to acquire a particular set of skills, but because he wanted the chance to merge his skills with a different skill set. He described his postdoctoral mentor has having a complementary set of skills, creating a "nice division of labor" in the research. The result has been a 15-year collaboration that has continued long into the faculty member's independent research career.

The Role of Institutions in the Ongoing Training of Early-Career Faculty Members

It became abundantly clear over the course of the interviews that faculty members saw their development as collaborative researchers as an ongoing process. For some, their faculty careers were the first time that they had a chance to engage in independent research collaborations in which they retained the locus of control. For others, their collaborative work as professors was a chance to continually refine their skills, expand their networks, and develop fresh ideas.

For nearly half of the interviewees (8), centers within the university had proven instrumental in their collaborative endeavors. Centers served a number of purposes. For many, centers had become a place to meet colleagues, sound out new ideas, and gain support for grant proposals. A social scientist described the role of centers in her research life this way, "I think if we had more centers like that and people had a research affiliation, things could grow by leaps and bounds. I mean because I do feel like when I have a research idea they are going to support it. There are going to find some way to support it, you know?...Those types of places on campus, those moments and spaces are invaluable for my development I think."

A physical scientist recounted how a center at a different university brought him into a new research group at the inter-institutional and international levels by providing their campus faculty with the funding they needed to bring scholars in from across the globe for a research brainstorming session. They came to the meeting without a particular project in mind, but to meet, get to know each other, network, and discuss how they might collaborate in the future. The activity led to a $5 million multi-institutional grant for overseas field research. This speaks to the important leveraging centers can do as they support faculty members' new research ideas and serve to increase capacity through the establishment of linkages to scholars outside the immediate environment.

Similarly, a faculty member at the university spoke of how her center affiliation on campus had served as a mechanism for gaining new affiliations with scholarly networks beyond the campus. There was a networking component to this, as well as a skill development component. On the networking side, the national reputation of the center attracted talent from knowledge hubs across the country and world. By being on the center's faculty affiliate list, she was frequently connected with new people looking to collaborate with the center on an area of

research related to her field of specialization. On the skill development side, however, the faculty member reported how she had participated in a center-sponsored seminar on interdisciplinarity. In her words, “I think I learned the most about interdisciplinarity, which is misused and misunderstood across the board. I joined a faculty seminar for the Center…[which] actually taught me a lot, including [about] interdisciplinary. My colleague and I, we were both in that seminar one semester preceding the semester that we taught together.”

Centers, especially area studies centers with different geographical foci, were also seen as places that facilitated research involving international collaborations. Faculty members reported limited endorsement within their own academic departments for international research and international partnerships. However, centers were places that connected colleagues from different disciplines with a shared regional focus for dialogue and other collaborative activity. A social scientist described it this way, “I find a little bit more, you know, comfort in the regional center where there are their own biases towards arts, and culture, and languages. I just find much more appreciation of the kinds of things that are frowned upon [in my academic home department].”

Just as centers facilitated collaboration among researchers from different disciplines with a shared regional focus, centers also facilitated collaboration among researchers from different disciplines with a shared interest in a particular research area. A physical scientist described the center that she is affiliated with as attracting the federal grant dollars and the scholars from around the country that she needs in order to engage in high-level interdisciplinary research. By serving as a hub for sponsored interdisciplinary research, her center introduces her continually to new ideas, new people, and new opportunities for research.

A life scientist described a new type of center that had proven critical to his own successful research program. The university had established a number of core laboratories for the purpose of providing localized expert support on research projects. These labs are staffed by highly trained scientists, and they remain neutral with respect to particular academic departments, in as much as they provide free or heavily discounted guidance and lab expertise to anyone who comes to them, regardless of their home department. The benefit of collaborating with these labs was seen as multifaceted. They were seen as cost-effective, providing expert guidance, enabling access to key technologies and equipment, and a way to collaborate locally with a dependable and trustworthy collaborator. Because the core labs' viability is tied to their ability to connect with faculty members and provide them with the fee-based services needed in the performance of their research, they were seen as dependable and inherently trustworthy. In the words of the life scientist who brought these core labs up, "They have the mindset that they want to help other people's research rather than do their own."

In addition to the on-going roles that campus centers play in helping faculty members hone their collaborative skills, connect with relevant colleagues, and gain access to key components for their research, nearly a third of the interviewees spoke of how important faculty peer-mentoring is to their continuing development as collaborative researchers. All of these respondents were faculty members at the assistant professor rank.

A new professor in engineering spoke of how she collaborates with senior colleagues in her department to develop her ideas, identify areas where collaboration is needed, and find potential collaborators at the departmental, intra-institutional, and inter-institutional levels. She specifically appreciated her colleagues' willingness to help her tap into their own engineering networks. This idea of working with senior colleagues to work through new ideas and identify

areas where collaboration would be useful and advisable was mentioned by 3 of the 6 interviewees who brought up peer-mentoring as an important contributor to their development.

There were also assistant professors in the interview pool who cried out for peer-support within their academic department, and felt that they were lacking it. One faculty member, an international woman in her first year on the faculty reported feeling, “too young and naïve.” She went on to assert that, “Senior colleagues wouldn’t be interested in collaborating with me.” That being said, she felt strongly that her senior colleagues could be instrumental in introducing her to new networks and in helping her become more collaborative.

Another assistant professor from an engineering program expressed his frustration with what he perceived to be favoritism expressed by his senior colleagues within the department. While he expressed a strong desire to be mentored and learn the ins and outs of his profession from his more experienced peers, he saw his peers as unreachable for him. In his words, “There are protected species [in the department], and there are some that they don’t want to protect. So apparently I’m outside the protection zone.” He went on to explain that for him, this meant that he was more on his own in terms of finding colleagues across campus and beyond to collaborate with. However, he saw his younger peers within the protection zone and getting much more guidance and assistance with collaboration.

Relative Importance of Different Experiences in Developing Collaborative Research Acumen

When discussing the relative importance of faculty member’s pre-career developmental experiences related to collaboration, responses fell into three categories: those who felt that their undergraduate or graduate programs had been foundational, those who felt that their postdoctoral

research experiences were the most important, and those who felt strongly that each experience contributed independently but in a synergistic way to their overall development as collaborative researchers. For those who focused on their schooling, whether undergraduate or graduate, faculty members spoke mostly of these times as fundamental to the development of their core understandings and principles. A physical scientist spoke of his undergraduate career as foundational to him in the development of his understanding that academic departments are artificial silos that demand collaboration in order to break out of those intellectual confines. This was the only faculty member who cited his undergraduate experience as the most important to his development as a collaborative researcher.

For the remaining participants who indicated their schooling had been foundational, graduate school was seen as the most important. A social scientist explained that, "My graduate training was huge, [and] part of that was in terms of [developing] research tools and philosophy. It wasn't all collaborative. I think the feminist training that I received was inherently not collaborative, but mutually beneficial…[But I learned that] research should always be with a purpose. Just learning how to do qualitative research – research design – those things have carried me through." Similarly, a life scientist described his graduate school days as critical to learning the skills he needed to do high-level research. A physical scientist described how his Ph.D. mentor had been a geologist who worked in biology, showing him how one can take a particular skill set and apply it to a new field. He went on to explain how interdisciplinary Ph.D. programs teach their students how to talk with people and to interact with people across disciplines. These examples represent a consistent theme across many of the interviews, which is that graduate school was seen as absolutely essential to the development of the skills and perspectives needed to engage in collaborative research. This scholarly development was

indirectly related to collaboration in that it was development of human capital itself, the process of becoming highly skilled, that built up their confidence in their abilities and made them valuable within the context of a collaborative network of scholars. Collaboration with poorly trained researchers, in other words, is not too likely.

While this indirect training toward becoming responsible, engaged, and qualified collaborative researchers was a strong theme running through the interviews, several interviewees also spoke of the direct collaboration skills they had learned as graduate students. An engineering professor spoke of how she simply became immersed in a collaborative research environment during graduate school and that's how she learned to work. In many ways, it had become a state of being, rather than a skill. She explained, "I was into collaboration from day one, and until the last day I was collaborating with different people in different regions because I wanted to do interdisciplinary work. So for me, I cannot imagine a moment where I did not collaborate…I can't point out one moment where I saw it. It was important, but I can't imagine a moment without it."

Another professor in the social sciences described a similar experience in his interview. He spoke of his mentor teaching him how to collaborate and engage others by modeling this behavior and constantly bringing him into collaborative field research projects. For him, the collaborative approach simply became his understanding of how you engage in social scientific research. This same faculty member described collaborating with a peer in his doctoral program to put together a conference paper that ended up getting published in a top-tier journal. He recalled this experience fondly and how it taught him that collaboration could be "lateral" rather than always "hierarchical." For him, he took from this experience that if you do good research,

align yourself with good people, work hard, and trust in others as you trust in yourself, the merits of the outcomes will be recognized.

For another group of faculty members, the Ph.D. had been important in the development of skills, but the postdoctoral research period had been instrumental in transferring those skills to a collaborative enterprise. One engineering professor spoke of how her postdoc had really transformed her perspective and shown her the power of collaborative work. In her words, "My grad school lab was one of those, you know, megalabs with a dozen researchers [and] 50 graduate students. My postdoc was a one-man show with maybe 10 students. So I got to see a little bit more how I might have to implement a one-man show [which necessitates collaboration]."

A physical scientist described his postdoctoral mentor as teaching him how collaboration can be instrumental in keeping research fresh and following new projects that interest you, despite skill-based limitations. He described his postdoctoral mentoring this way, "What she taught me was, you know, always think big. Always look wide [and] don't be afraid to ask for help. It doesn't diminish you in any way. And the more you sort of put a perimeter around your research, the less likely it's going to be successful…She just sort of said – you know these boundaries are artificial. You have to do just what interests you and that may mean pushing yourself out of your comfort zone, but also pushing yourself into collaborations that might not feel comfortable at first." This was a perspective that many interviewees reported having instilled in them by their mentors.

For a smaller group of respondents, the synergistic qualities of their many developmental experiences were emphasized, rather than assigning primacy to one particular developmental period in their preparation. One engineer, for example, spoke of her doctoral work and her

postdoctoral research as equally collaborative and foundational. However, she saw these experiences as bringing in different facets of collaboration. For her, her time as a doctoral student was a time to learn how to work as part of team. This entailed doing good work, being on time, and following the directives of her doctoral program advisor. This was not a particularly creative time for her, but her work was intimately involved with that of those around her. In contrast, she described her postdoctoral research as much more collaborative on an intellectual level. In her words, "At my postdoctoral work, I did still a lot of collaborations, but I also did a lot of intellectual collaborations or you know, I was given a component by someone and I have the idea all throughout my research. I was always, in many occasions, I was given a component by someone and then I had the idea to use that component for a completely different outlook." What this interviewee was describing is the increased autonomy she experienced as a postdoctoral researcher. She was still reliant upon, and collaborating with others in the performance of her research, but she was allowed the freedom and expected to bring her own creativity and innovation to the research problem at hand.

For other faculty members, they saw their time as graduate students and postdoctoral scholars as fundamental to network development. A life scientist explained, "I start to build a network…You do research during your Ph.D. and you see the importance of collaboration. And you do the research during your postdoc and you also see the importance of collaboration…We are exposed to that kind of thing from the beginning." For this scholar, and many others, their developmental experiences were indeed seen as fundamental to their network development, and many referenced on-going and highly active collaborations with their former mentors from their doctoral and postdoctoral times, as well as with the research partners that they had been exposed to during those periods.

Lack of Pre-Career Training in Collaborative Research

While all interviewees indicated active collaborative engagement with colleagues on multiple levels, two women, both international faculty members from different regions of the world [Asia and Europe], and both working in the social sciences, expressed frustration with the lack of training they had received in collaboration. Neither professor had pursued postdoctoral training, but both acknowledged how critically important collaboration is to their research. The difficulty both expressed is articulated well by the faculty member from Europe, "I wasn't taught [how to collaborate]. I wasn't taught all that in the graduate school or throughout my mentorship and kind of professionalization. I think what would have helped is this kind of mentoring that is geared towards women or women of color, or minorities of other kind. Where you know, everything that is underneath and that is claimed not to exist is put up front on the table and you are just blankly explained that this is how things are…Sometimes you get a gut feeling of you know something is off, something is off. But it's just, you know, the way the institutions are structured. Um, and if there was like a good feminist scholar, or critical scholar and activist in the profession who would have you know, just spoke frankly and you know warned us and guided us about how to be prepared and handle those kinds of challenges. Because I'm learning [to collaborate] by trial and error and it's kind of – I'm rolled back. I mean I feel like I'm a bit behind."

The interview excerpt above followed a discussion about how difficult collaboration is for international women due to cultural and skill-based barriers. On the cultural front, both women spoke of how difficult it is to assert themselves in scholarly venues. For the woman from Asia, walking up to someone at a conference, for example, was seen as presumptuous and boastful. This was not something that someone in China would do, especially if the person was a

prominent scholar in the field. Similarly the woman from Europe expressed her reluctance to engage with scholars she doesn't know at conferences because she is so unknown. In terms of skills, both women spoke of how difficult it is to internalize the skills of social networking at professional venues. From greetings, to talking about one's own research, to challenging the assertions of more prominent scholars working in similar areas, these were considered difficult hurdles to overcome. Furthermore, as the quote above indicates, both women reported encountering hidden biases among their colleagues in the field related to their gender and national origin. These biases will be explored in more detail in the final section of this chapter.

Constraints on and Opportunities in Collaboration by Subpopulation

Answering the last qualitative research question, the final section of this chapter explores the differences between international and U.S. citizen faculty members regarding the perceived constraints on and opportunities available to them as they relate to the development of collaborative partnerships. In particular, international faculty members' sense of their own advantages and disadvantages as non-citizens will be discussed. U.S. citizens' perceived advantages and disadvantages as they relate to their citizenship will also be discussed. Finally, barriers relating to gender and socio-economic class will be briefly mentioned.

Advantages for International Faculty Members

As international faculty members discussed the advantages they had experienced in the performance of collaborative research, several themes emerged. Some of these advantages were more logistical in nature, while others were more intellectual. On the logistical side, several interviewees spoke of how their strong family ties in their country of origin and their frequent

visits afforded them more opportunities to collaborate with scholars physically located in those countries. A faculty member from China explained, "My parents are living in another country, so I basically visit them regularly. So basically I **need** to go to the country. Previously we talk [earlier in the interview] about the cost, the time, [but] you know I have to take a vacation for two weeks to bring my kids to see their grandparents, their grandmas. Then I can piggyback that trip with colleagues in that country, so that we can start collaborating. I spend probably one week with my family. I spend one week talking with my colleagues there. So I think that certainly helps [with international collaboration]." This was a familiar theme, especially for those whose country of origin is located a long way from the United States. A Korean and a different Chinese faculty member both spoke of making trips home to family and connecting with colleagues at the same time. Many of these professional linkages were with colleagues who they had met when pursuing their Bachelor's or Master's degrees in their country of origin.

The same faculty member who spoke about returning to China to collaborate with colleagues in his country of origin, described another form of logistical collaboration that he engages in. Because of the prevalence of Chinese scholars in the United States, he reported that he is in high demand within the U.S. because of his ability to connect scholars with the U.S.-based networks of Chinese scholars. Because of his linguistic and cultural acumen, and his connections to the Chinese network he is able to help colleagues establish stronger ties within the U.S.

This phenomenon was bi-directional as well. While this particular faculty member spoke of his role in helping his university colleagues connect with U.S.-based Chinese scholars, a different faculty member from China spoke of her experiences at conferences in the U.S. and how she finds it quite natural to connect with other Chinese scholars there and discuss bringing

them into her own research networks. A comment made by an international faculty member in engineering brings into focus the power of linguistic and cultural knowledge in collaboration. He said, “We are collaborating with people, we are not just collaborating with ideas.” This emphasis on the interpersonal dynamics of any collaboration is an important concept to keep at the forefront of our understanding.

Linguistic abilities were seen as a major advantage for international faculty members. On the one hand, some faculty members reported having natural affiliations with areas studies centers on campus because they spoke a relevant language natively. This brought them more easily into interdisciplinary collaborative contexts. On the other hand, faculty members spoke of their advantage working with collaborators abroad who do not speak English and their ability to conduct field research using their native tongues.

On the intellectual side, several interviewees spoke of the unique cosmopolitan perspective that they bring to their collaborations. Because of their training, their mobility-related exposure to different networks and knowledge hubs, and their cultural and linguistic foundation, they felt that they brought a great deal to their research collaborations. Furthermore, a U.S. citizen who was interviewed felt that her international colleagues, because of their more worldly experience and because of their connections to scholars abroad, were naturally less intimidated by the prospect of engaging in international collaborations.

Challenges for International Faculty Members

While many international faculty members cited knowledge of another language and cultural awareness as advantages to their collaborations, others spoke of language and cultural heritage as disadvantages. In terms of language, international faculty members spoke of how

being non-native speakers of English creates barriers for them. As a social scientist explained, language can be learned and learned quite well, but a non-native speaker will never be as articulate in English as their [native English-speaking] colleagues. Whether this perception is true or not, several faculty members spoke of the reluctance of colleagues to co-write papers with them because of their non-native writing styles. Co-authoring would mean a greater burden for the writing for the native speaker of English and a lower likelihood of publication.

By way of explanation, a recurring theme, even on independently produced articles and other publications, was how much money and time international faculty members spend to have their papers proofread by native English-speaking experts prior to journal submission. Furthermore, even after having their work proofread, a pronounced bias against non-native speakers among top-tier journals was strongly felt by many interviewees. Several international faculty members, in fact, indicated that they had stopped sending their articles to American scientific journals because of this bias. In the words of an international professor in engineering, "Some journals focus on language, not content. So you learn not to submit to those." Instead, many international faculty members reported sending articles to top European scholarly journals because of their more egalitarian approach to language.

On the cultural front, several interviewees, especially those from Asia reported difficulty reaching out to colleagues for new collaborations. This was especially articulated as a barrier at conferences when meeting people for the first time. As one faculty member explained, "I think I have not been vocal enough. I have not been putting myself out there [and] speaking about my accomplishments, about what I have to offer – like really really bragging." She went on to say, "I grew up in a community culture that did not teach me [to brag], you know, it's not [an]

individualistic culture where you stand up for yourself…I'm not good at networking. And I'm not that good at networking because I've never been taught this skill. You know?"

While this comment came from a faculty member from Europe, this idea of finding it difficult to "brag" about ones skills and research agenda was a common theme. A new professor from the social sciences who hailed from China explained how hard it is to connect with her U.S. colleagues because she's not used to being "aggressive" or "assertive." She characterized her American colleagues as "boastful" when talking about their research. Furthermore, as a young Chinese woman, she reported finding it very difficult to overcome her cultural deference to scholars with seniority. Approaching senior colleagues was viewed as presumptuous and acting beyond one's station. While everyone interviewed acknowledged that they understood how the U.S. academic culture works and how they "should" behave, many reported feeling uncomfortable interacting in this environment and ignoring ingrained cultural edicts.

Advantages for U.S. Citizen Faculty

There were several perceived advantages experienced by faculty members holding U.S. citizenship. Most of these advantages were on the more logistical side as they related to collaboration. While language and culture were not articulated as issues for U.S. faculty members, their international colleagues did see U.S. citizens as having natural advantages in this realm. In the words of one international faculty member, "I didn't grow up here. I didn't do my undergraduate here. I was not taught a lot of social skills, and even though I feel very confident about my language, it is still not where the language of my colleagues [is]." She went on to explain that she views her U.S. colleagues as much more "articulate" and "persuasive" and thus able to attract collaborations much more easily.

This did come up in one interview with a U.S. faculty member from the life sciences. In discussing his own sense of how his U.S. citizenship had affected his collaborations he stated, “If anything else, in part because I have the cultural context of the U.S., [it] probably makes me more sought out, in the fact that there are strong things in the U.S. and the fact that we have a pretty strong research component. I am probably reaping the benefits now when people call me on the phone or send me an email asking me to send stuff to them.”

Several U.S. respondents did speak to the ease with which they are able to collaborate within the U.S. context. While it may be perceived that language and culture are a part of this, it was also pointed out that access to U.S. government research funding to support larger collaborative projects was more available to those with U.S. citizenship or permanent residency. A physical scientist, for example, spoke of the rich array of resources available to her to support her collaborative research. These resources were seen as attractive to collaborators from abroad especially, so garnered her attention from colleagues both near and far.

A final area of logistical advantage for U.S. citizens was the fact that most of their professional conferences were located in the United States. This enabled more frequent in-person collaboration with colleagues from their broader scholarly network. While many international faculty also spoke of the importance of conference attendance and their active participation in such opportunities, U.S. conferences were not dependable mechanisms for connecting with colleagues from their country of origin. Thus, while science is becoming more global in many respects, U.S.-based opportunities for in-person collaboration with known peers are more plentiful for faculty members who have most of their scholarly networks based in the U.S.

Challenges for U.S. Citizen Faculty

From the perspective of several international faculty members, their U.S. citizen colleagues were at a significant disadvantage when it came to participation in international scholarly conferences. An engineering professor from China explained it this way, "Pick up a faculty member who grow up in the U.S., go through all formal training in the U.S. Then if that person, she flies [for a conference] to Cambridge [England] and also she flies to Beijing [China], which place is easy for her to find collaborator? I would say Cambridge. If you put me outside of this Chinese circle now, I would view everything equal." What is interesting in this statement is its assertion that a scholar's propensity for international collaboration with colleagues is not driven by mobility, but by how similar different countries' cultures are. For this international faculty member, he felt that he would be more adept at collaborating internationally with colleagues from China, Korea, and Japan. For his U.S. citizen peers, however, he felt that they would be better able to collaborate with colleagues from the United Kingdom and Canada. This feeling seemed to be shared by at least one U.S. colleague who stated that it is, "Probably easier for the international people to collaborate with their home country [than it is for me to collaborate with people in that country]."

Another international faculty member spoke of the difficulty he observed among his U.S. colleagues in understanding the value of engaging in international research collaborations. From his perspective, he felt that his U.S. colleagues were more U.S. centric in their views and had never really "experienced the carrots" associated with international collaborative research. Nor had they had to develop the skills to overcome the natural barriers to international collaboration. This was backed up somewhat by a U.S. colleague in the same department who spoke of the difficulties she had experienced in engaging in international collaborations because of her lack of

experience and the unanticipated barriers. She said, "Having been in the U.S. and having most of my collaborators in the U.S…it doesn't always become apparent to you that people do things a different way. And so for instance, that issue with the Norwegians [a particularly difficult collaboration she had described earlier], they were actually very very concerned about me, as an American, stealing all of their work. It was a shocking – jarring experience because I had no idea – that hadn't even occurred to me that I would be doing that." This comment speaks to the importance of gaining experience in international collaborations for U.S. citizens in order to overcome perceptual and cultural barriers.

It is interesting to note that only two out of the 10 U.S. citizens could articulate barriers that they experienced as they related to their citizenship status. Most interviewees slipped into discussing the difficulties they had experienced because of the fact that they were located in the U.S., rather than because of their cultural or linguistic heritage. Issues related to collaborating with colleagues from different time zones, on different funding cycles and with different funding agency reporting requirements, for example, could easily be experienced by all U.S.-based faculty members whether they were U.S. citizens or not.

Gender, Socio-Economic, and Discipline-Centered Barriers to Collaboration

While this was not a particular focus in the interviews, several interviewees brought up gender-related and socio-economic barriers that they had experienced when trying to collaborate with colleagues. Two interviewees drew attention to gender issues that they had experienced. Both women worked in the social sciences, with one holding U.S. citizenship and the other an international faculty member. For the international faculty member, she reported feeling like a "triple minority" as a "woman," a "woman of color," and as an "international woman of color."

In describing how this affected her collaborative efforts she spoke of how she felt that an underlying sexism made it more difficult for her to gain respect from her male colleagues within the department. She also spoke of how her male-dominated field was difficult to break into in her attempts to collaborate.

For the U.S. faculty member, she explained her own experiences with gender-based discrimination from her colleagues, which affected her feelings with regard to her collaborative approach to research. In her words, "I am a woman. I am a woman who's a chair. That makes life even more complicated…I have faced discrimination on the job. I have faced discriminatory comments from faculty here, and in other positions that I have been in. It's a part of how I think about things. I am, sadly, still a bit too feminist. I try hard to fight that, to be honest with you, because I think it works against my ability to be completely fair and honest, and straightforward as a chair…I feel apologetic most of the time [for her collaborative approach], which is probably why I embraced this interview as much as I did. I feel apologetic for my research program among my colleagues, **period**." In discussing this further, the faculty member explained that her collaborative nature meant that her research profile was more eclectic and more difficult to understand as a unified program. That, combined with her gender, made it harder for her to achieve promotions and she felt that she had to work harder and longer than her male colleagues. She explained, "I'm in a minority status in the type of researcher I am. I know there are costs associated with that. I know that I don't get – I will never be respected at the highest levels. Yes there are times when that makes me sad or frustrated, or unhappy. Just like any minority would be…I'm darn happy with who I am and how I do research. And I think the payoff for me is longevity!"

In terms of socio-economic class a very interesting dichotomization emerged between a U.S. citizen and an international faculty member that really emphasized the importance of culture and place of origin in the performance of collaborative research. A social scientist described her humble beginnings as a barrier to international collaborative research. She asserted that those with wealthy upbringings and opportunities to engage socially in different contexts would be more apt to engage in what she felt were emotionally riskier activities like international collaborations. This was due, in part, to the typical sense of entitlement experienced by the elite. In her words, "I think if you are coming from a class deficit, you know, collaboration is scarier, international collaboration is scarier, just because you are more insecure. I mean I'm insecure every day in this job just because of where I came from. I think other people have a more, a more developed sense of entitlement because they have, of course, their fathers are Ph.Ds., their mothers are Ph.Ds. Anyway, that **might** help their collaborations."

This set of remarks stood in sharp contrast to an international faculty member from China, who did not share the same class-based cultural context. He explained it this way, "I never thought about that [the role of class in collaboration]. You know, I grow up in a middle class family in China. Of course at that time there's **no** middle class. They just make about $100 a year or something like that. The [economic] difference [between people] is very tiny. And so everyone was middle class. I came to the U.S. with 2 luggages…So in this part I think the Ph.D. training very important. It give[s] the person the right training and also the right confidence to collaborate with other faculty members." This reaction to the assertion that class may somehow affect an individual's comfort-level with collaboration shows how cultural context can interact with other factors within the individual.

Taken together, the results of the qualitative phase of the study suggest that faculty members are deeply engaged in collaborative research and that these collaborations increasingly transcend institutional and political boundaries. Furthermore, interviewees' expanded notions of what constitutes collaboration reinforces the importance of focusing on the processes of collaborative research, rather than on the products of collaborative engagement alone that can be traced back to multiple contributors. Tangible and intangible forms of collaborative behavior were a dominant theme to emerge from the interviews. The faculty members interviewed articulated a diverse array of mechanisms that they employ in developing and maintaining collaborative networks, as well as a broad range of reasons for wanting to engage in collaborative research in the first place. From the pressure of earning tenure or a promotion, to overcoming the challenges of producing novel research, faculty members actively used their collegial networks (ties), conference attendance, and even their teaching and mentoring to develop their collaborative networks. One of the most pronounced findings in the qualitative phase of the study was the discovery that all faculty members had collaborative experiences prior to their postdoctoral research periods and/or prior to beginning their faculty careers. This suggests that faculty members are trained within an environment that is collaborative by nature and that reinforces, at least to some extent, the importance of collaborative research from the very beginning. Finally, interview data focusing on citizenship status, gender, and socio-economic status suggest that while faculty members' personal backgrounds create inherent challenges and provide natural advantages in the realm of collaboration, faculty members are able to engage in all forms of collaborative activity studied here.

The concluding chapter that follows will discuss and integrate the findings of the two phases of this study, explore their importance and implications, and articulate future directions

for research. With regard to the implications of this study, specific attention will be given to the implications for institutional policy makers, granting agencies, and academic departments engaged in the training and development of tomorrow's collaborative researchers.

CHAPTER 6: CONCLUSION

The overarching purpose of this study has been to develop a better understanding of the patterns and processes of collaboration in the performance of research, as well as to understand why and how early-career faculty members engage in collaborative partnerships. With an eye toward institutional policy and academic programming, special emphasis was also placed on how faculty members perceive the role of their diverse developmental experiences as they relate to the acquisition of collaboration skills.

Following the order of the research questions that have been posed, this chapter begins with a discussion of the results of the two phases of this study. Collaboration patterns are discussed as informed by the study's quantitative and qualitative results. This is followed by a discussion of the factors that predict different forms of collaboration according to the SDR, as well as the primary motivations behind and mechanisms for engaging in collaborative research as learned from interviews. Referencing the third qualitative research question, the study's focus on the respective importance of various developmental and training experiences is then explored as these experiences relate to the development of collaborative research skills. The section concludes with a discussion of the findings related to citizenship status. The importance and implications of the study's findings are discussed next, focusing in particular on how they inform both research and practice. In particular, this section focuses on how the study's findings relate to social network theory's strength of weak ties concept, lessons to be learned from the perspective of institutions of higher education, and the power that external funding agencies have to foster or hinder collaborative research. The chapter concludes with a summary of the study's main findings, limitations and directions for future research.

Discussion

Collaboration Patterns

The forms of collaboration that faculty members reported engaging in were the focus of the first research question for both phases of the study. For the quantitative phase, data from the 2006 SDR were examined to determine the prevalence of team-level, intra-institutional, inter-institutional, and international forms of collaboration in early-career faculty members' lives. Similarly, in the qualitative phase of the study interviewees were asked to describe their collaborations at the departmental/team level, within the university, with colleagues at other universities within the U.S., and on an international level.

A comparison of the results of these two phases of the study yielded differences that suggest some degree of caution should be used in interpreting data on collaboration from the 2006 SDR, as well as in interpreting data from the qualitative interviews given that interviews were only conducted on a single Research I university campus. The results also have implications for future quantitative studies examining collaborative processes among faculty members as the qualitative data on forms of collaboration suggest a rich diversity of collaborative engagement among this population. Unanticipated forms of collaboration were articulated in the interviews that challenge traditional understandings of collaboration and how it relates to scholarly productivity and the products of collaborative work.

With regard to the SDR data, the form of collaboration with the highest frequency across all groups was intra-institutional collaboration with nearly ¾ of respondents indicating that they had engaged in this form of collaboration in the performance of their research. For all subpopulations, with the exception of the international faculty subpopulation, team collaboration, inter-institutional collaboration, and international collaboration followed in that order.

International faculty members were the sole exception with inter-institutional collaboration coming after intra-institutional collaboration, followed by team collaboration and international collaboration respectively. International collaboration was reported with the lowest frequency across all groups. The descriptive statistics would suggest that the faculty members interviewed would be most likely to collaborate within their own institutions, but beyond their academic departments, and least likely to collaborate on an international dimension.

Furthermore, the descriptive data from the SDR suggest that differences might emerge related to faculty-members' self-reported collaborative activity and how that activity is predicted by factors such as gender and citizenship status. In particular, it was expected that U.S. citizen status would predict higher odds of indicating active collaboration at the local levels (team and intra-institutional collaboration), while their international colleagues would be more likely to self-report higher frequencies of collaboration at the national and international levels. The descriptive statistics on citizenship lend support to the assertion that mobility serves to expand faculty members' collaborative networks of ties beyond the campus (Cheng & Yang, 1998; Kahn & MacGarvie, 2008; Regets, 2007[a]; Saxenian, 2002; Szelényi, 2003), since by definition international faculty members have had greater personal mobility, at least in the past.

While grounded in national data on self-reported forms of collaborative engagement and in inferential statistics that explored for statistically significant predictors of collaborative behavior outcomes from among the independent variables included in the analysis, these predictions on the relationship between the factors considered and forms of collaboration did not hold true for the group interviewed. This is despite that fact that the interview population matched the characteristics of the population studied on the SDR, with the exception that all interviews were conducted with faculty members working at a Research I institution. As reported

in Chapter 5, with only one exception, all faculty members interviewed at the university self-reported utilizing all four forms of collaboration in the performance of their research. While the relative frequency of each type of collaborative activity was not ascertained during the interviews, it should be noted that the collaboration measures on the SDR were also all-or-nothing measures. In other words, an indication of "yes" for a particular type of collaboration on the SDR was in no way an indication of the frequency of collaboration at that level.

The data collected by NSF would indicate different frequencies across different collaboration types and differences in collaborative behavior patterns among different population subgroups. It should be kept in mind, however, that the SDR does not define collaboration outside of the specific questions related to the four forms of collaboration that have been articulated. Our understandings of what individual responses to these questions mean must take this into account and will be similarly limited. Semi-structured interviews with professors from a single institution, however, suggest that nearly all faculty members are engaging others in the performance of their research. Furthermore, interviewees indicated active collaborations across all four collaboration types under study.

While the exact reasons for the collaboration pattern differences between the SDR and the interviews call for additional research, part of the explanation may lie in the interactive nature of the interviews themselves. When completing a survey, a respondent must read a question, interpret the meaning of the question, and give their answer within a highly structured environment. Certainly this was true for the SDR in 2006. It may be possible, for example, that survey respondents assumed that they should only indicate "yes" for a particular type of collaborative activity if there had been a tangible and successful outcome from the collaborative activity that could be shown as hard evidence of productive collaboration.

Such tangible outcomes could include co-authored publications or successful grant applications, to name a couple. Indeed, in talking with faculty members, these more tangible outcomes and faculty members' perceptions of their importance with regard to such professional objectives as promotion and / or tenure, were cited regularly as sources of stress and tension among interviewees. This finding corresponds well with the literature on promotion and tenure that suggests faculty members feel a great deal of pressure when going up for tenure and/or promotion due to the need to demonstrate research productivity (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). Since we do not know how people interpreted the questions on the SDR, we cannot be certain as to what the frequencies of the four different collaborative activity types represent, nor can we truly understand why there might be statistically significant variation across the different subpopulations.

For semi-structured interviews, however, the interviewee and interviewer are engaged with one another and able to develop a mutually derived understanding of the questions being asked (Marginson, 2009). In the present study, this opportunity to interact led into rich discussions regarding the forms of collaborative research and called for an expansion of the definition of collaboration itself. Collaborative teaching, for example, was articulated as a form of collaboration that had powerful impacts on faculty members' thinking, perspectives, and research, but yielded little in the way of research products that could be easily identified as collaborative. The informal hallway conversations with departmental colleagues, discussions with colleagues from other disciplines at center-hosted workshops, and logistical support from international partners at a far- off field site were all considered examples of collaborative

engagement that didn't necessarily lead to co-authored publications or successful joint grant proposals.

In short, it became overwhelmingly clear over the course of the many hours of discussion that faculty members' collaborative activities lead to both tangible and intangible outcomes. Several respondents did indeed speak of co-authored grant applications that had turned into successful collaborations, co-authored publications, and co-presentations at professional conferences. This suggests an orientation toward collaborative activities that develop into high yield / high impact outcomes such as co-authored articles. This makes sense in light of literature that suggests that the fastest growing type of authorship structure consists of multi-institutional collaborations (Jones, Wuchty, & Uzzi, 2008), that collaborative research is more productive (Balog, 1979/80; Beaver & Rosen, 1978; Beaver & Rosen, 1979a; Beaver & Rosen, 1979b; Jones, 2010; Hodder, 1979/80; Katz & Martin, 1997; Lawani, 1986; Pao, 1980; Pao, 1981; Pravdic & Oluic-Vukovic, 1986; Price, 1963; Price, 1986; Price & Beaver, 1966), and that faculty members feel the pressure to produce research in a timely fashion in order to secure tenure and/or promotion (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). On the intangible side, however, faculty members spoke of collaborative proposals that failed to gain the funding necessary to produce the desired research, false or missing attribution of contributions on published articles, intellectual and logistical exchange with trusted colleagues, as well as the informal and formal sharing of knowledge and human capital through the elaborate scientific networks that faculty members develop.

While the intangible outcomes were no less significant in faculty members' research lives, they may represent a collection of activities, connections, and involvements that were not

elicited by the collaboration questions on the SDR. Importantly, none of the faculty members interviewed started their discussions on the type of collaborations that they had engaged in by talking about failed collaborations or collaborations that had led to intangible outcomes. Those collaborations that had manifested themselves in more tangible results (team-taught courses, co-authored papers, conference panel participation, co-edited volumes, et cetera) were the first to come to mind. What became clear over the course of the interviews, however, was that faculty members from the university were highly engaged with their colleagues in the performance of their research and that engagement included, but extended far beyond the department and into knowledge hubs across the world. This finding certainly supports, at least in part, the "death of distance" concept in which researchers are able to use technological advances in communication to bridge the physical distance between them and their collaborators (Jones, Wuchty & Uzzi, 2008). Overall, collaboration cannot be understood in the context of these interviews as simply a series of individual acts of engaging others in an effort to meet a particular project's end. Collaboration was much more organic and represented a way of life for the researchers interviewed. As such, any and all colleagues could be engaged at multiple points.

Data-Driven Predictive Factors for Collaboration

Turning again to the quantitative stage of analysis and the final quantitative research question on the predictive factors related to different forms of collaboration, logistic regression models were built for each collaborative form. As reported in Chapter 4 and summarized in Table 4.15, field of study was the single best predictive factor related to collaboration, especially with regard to collaboration at the team and intra-institutional levels. For these two forms of collaboration, the odds of engaging in this kind of work were significantly higher for those in the

life sciences, engineering, and physical sciences than for their colleagues in the social sciences. Only the odds of engaging in intra-institutional collaboration for those in the physical sciences were statistically the same for those in the social sciences.

As might be predicted from the descriptive statistics that were reported, a faculty member's international status significantly increased the odds of collaboration at the international level. However, international status did not increase the odds of collaborating at the inter-institutional level, despite the fact that the descriptive statistics indicated a higher frequency of collaboration of this type among the early-career international faculty members surveyed as compared to their U.S. citizen peers. Furthermore, neither gender nor postdoctoral research history significantly increased the odds of collaborating at the team, intra-institutional, inter-institutional, or international levels.

While tenure status only proved a significant predictive factor on the international collaboration dimension, possibly because of the pressure associate professors experience to earn promotion to full professor in the post-tenure phase of their careers, as age and time since degree increased so too did the odds of collaborating at the team level. Faculty members were 9.3% more likely to collaborate at the team level with each additional year post-Ph.D. completion, and 1.9% more likely with each additional year of age. It is interesting to note that age was not as strong a predictive factor as years since earning the doctorate. This suggests that experience post-completion of the Ph.D. was more important in predicting collaborative behavior at the team level than a person's life age. In other words, getting older is not so much a predictor of collaboration habits, as much as gaining research experience after the acquisition of a high level of field-relevant human capital. This speaks to the notion of collaboration as a skill developed over time, rather than as an innate quality or set of abilities. Just as researchers have been shown

to be more experimentally innovative over time and with experience (Weinberg & Galenson, 2005), respondents seem to develop more team collaborations with time and experience.

When examining the SDR data by Carnegie classification, it became clear that institutional type also played a major predictive role, especially with regard to team-level, inter-institutional, and international collaboration. Carnegie type was not a significant predictor of intra-institutional collaboration, most likely because this type of collaboration was already so highly engaged in across the different subpopulations. For team-level collaboration, however, those attending Research I, Research II, Doctorate Granting II, Comprehensive I, and Medical schools had significantly higher odds of collaborating than their peers at other institutional types. At the inter-institutional level, the odds of collaborating were higher for those working at Research I, Research II, or Doctorate Granting II institutions. On the international dimension, those at Comprehensive I institutions, as well as at Liberal Arts II institutions had higher odds of collaborating.

Taken together, these results suggest that different forms of collaboration are encouraged and supported differently across institutional types. They may also suggest that collaborative engagement in the performance of research may relate to the emphasis individual faculty members place on teaching, research, and service respectively within their careers. Team level collaboration was predicted by the greatest number of institutional type variables, followed by inter-institutional forms of collaboration. In other words, where you work, does make a difference on the less prevalent forms of collaboration.

Interviewees' Preparation for, Motivations behind, and Mechanisms for Establishing Collaborative Networks

The results of the qualitative interviews suggest a more nuanced understanding of the drivers of collaborative research and what those drivers are affecting is called for than might be derived from the results using SDR data. Moving into the second qualitative question regarding the mechanisms employed in the development of collaborative networks, how those networks are maintained, and why collaborations are pursued in the first place, if field, citizenship status, age, time since the doctorate, and institutional type were significant factors related to faculty members' collaborative behavior on the SDR, some degree of variation among the faculty members interviewed would be expected based on their own fields, background characteristics, and time since receiving their doctorates. As interviews were only conducted at a Research I institution, the role of institutional type could not be cross-examined in this study. Even without the ability to examine variation by institutional type, however, no variation was found related to the other background characteristics examined in the quantitative data. Every single faculty member collaborated at the team and inter-institutional levels, and all but one faculty member collaborated on the other two dimensions under study.

Part of this divergence from what was expected may be explained by the fact that the faculty members spoken with had long histories with collaborative research and truly saw collaboration in its many forms as a way of life. Interviews brought to light the fact that engagement in collaborative research had started well before faculty members' university careers had begun, and even prior to their time as postdoctoral researchers. Ranging from middle school to graduate school, with the majority of interviewees (11 of the 20) having had their first collaborative experience in graduate school, those interviewed unanimously recalled these early

experiences and saw them as part of their developmental history and engagement in collaborative research. While we do not know what happens to students who do not gain these early formative experiences in collaboration (they may choose not to pursue faculty careers, for example), we do know that all faculty members interviewed had these experiences prior to beginning their faculty careers and for those who had postdoctoral research experiences, their collaborative work had begun prior to that period as well.

The divergence in collaboration patterns between the SDR respondents and the interview informants may also be in part due to the fact that the interviews were all conducted at a single Research I institution. As institutional type, and the Research I type in particular, has been shown to be a powerful predictor of the forms of collaboration, with the exception of the most subscribed to form of collaboration (intra-institutional), it makes sense that the faculty members interviewed at a Research I institution would have greater odds of collaborating at the different levels examined in the study. Intra-institutional collaboration has been shown to be the most prevalent form of collaboration by the SDR data, and for team collaboration and inter-institutional collaboration alike, respondents from Research I institutions had the highest predicted odds of collaborating at these levels, as compared to any other institutional type. In other words, interviews were conducted at an institutional type with the highest likelihood of collaborative activity across all levels but the international dimension.

We also know from the interviews that regardless of their motivation to engage in collaborative research, the establishment and maintenance of research connections was a major priority for the faculty members spoken with. From acquiring competitive external funding or earning tenure and/or a promotion, to the learning of new things and engaging in projects that capitalize upon and synthesize the experience and depth of knowledge of multiple scientists,

faculty members self-reported a highly complex and multilayered set of efforts to engage and maintain that engagement with the local, national, and global research community. This supports the assertions of agencies and researchers alike that the nature of scientific research has become more complex and simply demands collaborative work (Koschmann, Lewis, & Isbell, 2011; NSF, 2011; Ribes & Bowker, 2011).

The Development of Collaboration Skills

The realization that interviewees' collaborative experiences had begun long before their faculty careers had started or before pursuing a postdoctoral research experience made it difficult to answer the third qualitative research question directly regarding the relative importance of various developmental and training experiences in faculty members' lives. While respondents clearly felt that they gained important skills and insights related to collaboration from their undergraduate, graduate, postdoctoral, and early-faculty careers, interviewees were unable to rank order or prioritize these experiences. Instead, most informants compared and contrasted their multiple experiences collectively and talked about the novel insights they had gained from and choices they had made as a result of the *system* [emphasis] of experiences as a whole. This suggests that there is not a particular sequence of training experiences or set of characteristics related to those experiences that must be engaged in, in order to develop collaborative habits in the conduct of research. Indeed, even those who had not had a postdoctoral experience reported engaging in all forms of collaboration, as did those who had highly isolated research experiences as graduate students or postdoctoral scholars.

Collaboration Differences by Citizenship

Network development in particular was seen as hugely important to faculty members regardless of their citizenship background. The awareness of and focus on network building supported the use of social network theory and the strength of weak ties hypothesis to frame this study (Burt, 1992; Eddy, 2010; Granovetter, 1973; Granovetter, 1983). Whether it was attending conferences, attending agency- or university-sponsored workshops, making use of known colleagues' more distant connections, or simply following up directly with those publishing cutting edge research in scientific journals, the establishment of human connections was seen as fundamental to research and these mechanisms were reportedly actively being employed by the faculty members interviewed. Nearly every single faculty member interviewed spoke of the necessity of collaborating with others on multiple levels in an era of such complexity and specialization. To push knowledge forward and address the research questions at hand, working with others was seen as essential.

What was not borne out in the interviews, however, was the sense that the modern technological era had led to a complete death of distance in which people's proximity to each other no longer mattered. While it is true that all faculty members reported engaging in all four forms of collaborative activity, it is also true that to a person, interviewees spoke of the importance of building connections in person. While technologies such as email and video conferencing were seen as fundamental to *maintaining* [emphasis] contact with collaborators, opportunities to meet people in person at conferences, to serve on panels together, to attend workshops together, to work out logistical details at a research site together, to teach together and learn from each other over the course of a semester, were seen as essential and powerful drivers of ongoing collaborative activity.

Several interviewees spoke of how important it is to argue with colleagues and to engage in less directed back and forth conversations where knowledge is shared not for a particular project goal or to accomplish a particular task, but to explore ideas more organically and light upon new and unanticipated concepts that would be interesting to explore together. The unstructured nature of in-person conversation was seen as invaluable to the development of new ideas, whereas technology provided the means to have more structured and regular follow-up meetings to work through project-specific issues. All of this suggests that knowledge hubs continue to persist and that information access is still restricted to those who have the financial, travel, and technological resources at their disposal (Jones, Wuchty, & Uzzi 2008).

In light of the importance respondents placed on in-person connection making and support for the existence of defined knowledge hubs, it might be presumed that international faculty members, by nature of having more frequent opportunities or reasons to go abroad to visit family, friends, and colleagues, would be more likely to collaborate internationally. Indeed this was part of the rationale for the last qualitative research question regarding citizenship status and interviewees' perceptions of how that status either enhances or hinders the development of their collaborative partnerships. Significant differences by citizenship in the quantitative data suggested that status does in fact impact collaboration differently according to the type of collaborative activity under consideration.

While it was made clear in several interviews with international faculty members that they do in fact have stronger ties with colleagues from their home countries and regions and often extend personal visits to enable them to connect with those colleagues, it was also clear that international conferences, whether based in the U.S. or abroad, were the levelers of the playing field. By attracting scholars from different knowledge hubs around the world,

conferences, just as centers were shown to do on the campus level, served to build bridges between colleagues, irrespective of the location of their careers. This evidence suggests that while the strength of weak ties hypothesis remains incredibly relevant to collaboration, strong ties and weak ties are not necessarily geospatially defined, but rather defined by the quality and depth of the research partnerships themselves.

Further emphasizing social network theory's strength of weak ties concept and its relevance to collaborative research (Eddy, 2010), conferences were also articulated as a means for colleagues to introduce each other, identify talent to recruit to doctoral programs and labs, and learn about the activities of others. Sometimes the connections were direct between conference attendees. At other times, however, a poster presenter, a questioner at a session, or a panelist would peak the interest of an attendee and help that colleague forge a new connection with colleagues not at the conference. In this sense, conferences themselves reportedly served the dual purpose of helping faculty members maintain their strong ties, irrespective of their primary geographical location, while placing them in positions to expand their scientific networks into new areas through the establishment of weak ties that may later develop into stronger connections.

Implications of the Research Findings

Implications for Research

While the limited SDR data on collaboration seem poorly suited for examining social network theory and its strength of weak ties hypothesis due its complex and highly interpersonal nature, the qualitative results lent themselves well to such an exploration. Social network theory in general, and Granovetter's weak ties hypothesis in particular, were originally postulated to explain how individuals find jobs (Burt, 1992; Granovetter, 1973; Granovetter, 1983). The

concept claims that people who have a diverse array of weak interpersonal connections with people are more likely to hear about distant job opportunities than those who have a very close but much smaller collection of interpersonal connections. In other words, you are more likely to hear about a job outside your circle of immediate friends if your friends in turn are tied into a broader (and different) group of social networks themselves. Results from the interviews conducted in this study support the work of other researchers who advocate for the extension of this theory to explain the processes involved in collaborative research (Eddy, 2010).

Collegial networks figured prominently across the interviews. Most obviously, perhaps, people spoke of their networking efforts when participating in academic conferences or workshops. As mentioned previously, attendance at such venues resulted in opportunities to meet new people through introductions made by colleagues. Interviewees also reported using conferences to meet prospective graduate students, postdoctoral researchers, or even future colleagues on the faculty. All of these are examples of the strength of weak ties concept in action.

Beyond conferences, however, interviewees described a broad and complex set of networks and opportunities used to expand their collaborative networks. For example, more senior departmental colleagues reportedly served to introduce their junior colleagues to researchers outside of the academic department. University centers also served to bring people from disparate research areas together for interdisciplinary discussions on a theme of mutual interest. Furthermore, project-related colleague referrals on campus served to bring people together through their mutual connection with a single colleague.

Similarly, international field research often benefitted from the strength of weak ties between colleagues, rather than from the direct connections established through international

travel or experiences. As reported, a physical scientist conducting field research in Indonesia connected his U.S. colleague with his research partners abroad. This led to several successful research projects, grant opportunities, and eventually to a funded project involving everyone together.

While some connections were made quite deliberately to serve a particular researcher's or project's needs, many other connections were more serendipitous, resulting in unanticipated but highly rewarding projects. The researcher describing a multi-national interdisciplinary project involving the creation of memories in mice through the shining of light on their brains is a perfect example. His participation in this research project was facilitated by a third-party researcher who had the idea to bring three complex and completely different research areas together to address a novel research problem that none of the researchers could have developed on their own or addressed independently. It was the third party's knowledge of their independent research areas (strong independent ties with each researcher) and his ability to connect them with each other (establish weak ties that could develop into strong linkages) and integrate their work in novel ways that made the project so successful.

The organic picture of collaborative relationships that emerged from the interviews and the ongoing nature of faculty members' development as skilled collaborators, support the assertions of researchers who tie research collaboration processes to the strength of weak ties hypothesis (Eddy, 2010). This validates using this particular theoretical frame in future research that examines collaborative processes. What emerges that is new from this study, however, is the notion that collaboration is not the result of a series of discrete and sequential processes or developmental experiences, but has become infused in a systemic way throughout the research experience.

Those interviewed derived different lessons on collaboration from their training and ongoing work as independent researchers. Negative collaborative experiences ironically created incentives to collaborate with others to learn new skills that would make them even more independent in the future. Positive collaborative experiences often led in unexpected ways to new collaborations through new ties. Even richly independent activity, such as presenting a paper at a conference, served as a mechanism for increasing collegial awareness of other's research so that unanticipated collaborative initiatives could be pursued.

Taken together, these results serve to emphasize the assertions of scholars and institutions alike, that the future of research will be interdisciplinary, data-intensive, and collaborative, with collaboration playing an increasingly important role in scientific circles (Koschmann, Lewis, & Isbell, 2011; NSF, 2011; Ribes & Bowker, 2011). For research on collaboration itself, these findings have significant implications as they suggest that collaboration must be examined from a more systemic perspective since it involves complex networks and processes that connect researchers with others in the research community in myriad ways and with stunning and unanticipated results.

Finally, the findings of this research bring into focus a characteristic of the strength of weak ties hypothesis that is seldom highlighted. It is easy to think of the strength of weak ties as a static set of processes where strong relationships with certain people create opportunities for loose coupling with those outside a researcher's immediate collegial network. However, as several of the personal narratives make clear, the nature of the ties between people also become transformed over time. Weak ties established through strong ties often become strong ties in and of themselves and enable researchers to network more broadly than ever before across knowledge hubs. With information technologies and social networking tools enhancing our

ability to connect with others and foster those ties further, we are no longer confined to a geo-spatially defined knowledge network, but part of a network that is defined by the research questions that we ask and the tools and knowledge needed to arrive at the answers.

Implications for Practice

With regard to practice, this study has numerous implications. Kezar and Lester (2009), as well as Eddy (2010) make the case that facilitating collaborative research must be an intentional and deliberate effort that is informed by knowledge of the processes behind how collaboration works. The results reported here lend support to those notions, emphasizing the complexities involved in collaborative research, and the powerful impact our institutions have in either facilitating or inhibiting collaboration. What this study emphasizes even more, however, is how enormously influential institutions of higher education and granting agencies are in this process.

Institutions of Higher Education. The results that have been reported emphasize that collaborative experiences can and do occur at multiple points in a person's development as a researcher. From the undergraduate years to graduate school, the postdoctoral research experience and beyond, interviewees expressed how important their collective experiences had been and continue to be to their formation as collaborative researchers. While it is clear that not a single faculty member interviewed lacked an early collaborative research experience, what is less clear is how these experiences individually or cumulatively affect researchers' future collaborative efforts.

First of all, since all interviewees reported engagement in highly active collaborative research careers, it is impossible to say from this study that certain types of collaborative experiences are less useful than others, or that having collaborative experiences earlier are more beneficial. Supporting prior research (Koschmann, Lewis, & Isbell, 2011; NSF, 2011; Ribes & Bowker, 2011), collaboration in the present study was seen by most as a scientific necessity and neither negative previous collaborative experiences nor readily acknowledged barriers such as the added time, expense, or loss of control involved in research collaboration changed the fact that every single faculty member, save one, reported collaborating on all four levels.

What is clear in this study, however, is that exposure to collaborative activity is important and can lead to new connections and new collaborations (Eddy, 2010). It also became clear over the course of the interviews that understanding the value of collaboration and having the opportunity to engage in collaborative research helps faculty members develop new interests and maintain a sense of excitement regarding their careers. Furthermore, collaboration introduced faculty members to new concepts and ideas, often provided them with focus in their research, and enabled them to accomplish research goals that would have been impossible otherwise. Such activity, in the minds of those interviewed, facilitated their branching out from disciplinary silos and enabled them to capitalize upon the knowledge of others while bringing their own perspectives and expertise to the table. Collaboration was seen as a major mechanism for overcoming these widely perceived barriers (Howard, 2011).

In recognizing the value of research collaborations, institutions have a number of opportunities to instill collaborative skills and facilitate their use among students, postdoctoral researchers, and faculty members alike. For students, collaborating with peers and mentors were important learning experiences that interviewees claimed helped them learn how to collaborate,

when to collaborate, and why to collaborate. Jointly authoring scholarly papers as students, helping a faculty member with field research abroad, or learning how to take the results of bench work and turn them into grant proposals and academic papers were invaluable with regard to learning the value of working with others. These student experiences should be supported and encouraged by colleges and universities.

As a training ground for researchers and producers of cutting edge research, colleges and universities do not have the luxury of assuming that the people starting their studies or careers at their institutions have received a strong or uniform background in how to engage in collaborative research. This came up in several interviews, with faculty members feeling underprepared for their collaborative roles, despite (and sometime because of) their training and previous collaborative experiences. Some reported that their Ph.D. advisors had shunned collaborative research. Some reported that in pursuing their doctorate they had no chance to work with others and were trained to be self-sufficient in their research efforts. Others spoke of the cultural and linguistic barriers that made collaboration less comfortable or of the gender biases that affect their underlying collegial relationships. Still others spoke of their motivations for pursuing postdoctoral research opportunities as stemming from negative collaborative experiences and their desire to become more self-sufficient in their research careers through the acquisition of new skills.

Taken together, these lessons from interviewees speak to the importance of providing students, postdoctoral researchers, and new faculty members with the support, incentives, and opportunities that they need to engage in collaborative activities. From involving students in collaborative projects with peers and faculty members, to enabling postdoctoral researchers to float between labs and attend conferences in order to pull together disparate areas of activity

toward the successful completion of a project or the development of a new collaborative project, these experiences can help individuals hone their collaboration skills, develop coping mechanisms for the difficulties that they will inevitably encounter, and help them establish a realistic set of expectations with regard to the potential and limitations associated with collaborative research.

For faculty members in particular, comments from interviewees reinforce the power of campus centers to facilitate networking and the creation of new interdisciplinary and multidisciplinary collaborations. Their comments also spoke to the critical role that conference attendance plays in faculty members' lives with regard to establishing new and maintaining existing collaborations. Post-secondary institutions wishing to promote collaborative research among their faculty members could go a long way toward achieving this goal by supporting and expanding the presence of research centers on campus and by providing faculty members with the flexibility and financial support that they need to attend scientific gatherings.

Finally, for assistant professors and associate professors alike, the tenure and promotion processes were seen as fundamentally related to research collaboration. Mixed messages were received at the departmental, school, and university levels regarding the value of research collaboration. These mixed messages may be at least partially responsible for the stress that other researchers have found faculty members experience in their collaborative endeavors (Eddy, 2010).

The emphasis on sole-authored publications was seen as a major inhibitor with regard to collaborative research as well, and in some cases led faculty members to appropriate recognition for the collaborative work of their own research teams. While the nature of scientific research today, the funding environment, and faculty members' own drive to produce novel and ground-

breaking research provide the impetus for engaging in collaborative research, unclear messages, the active practice of discouraging research with others, and a lack of logistical and financial support needed to engage in collaborative research hinder it. Furthermore, strict tenure and promotion guidelines and timeframes inhibit participation in large complex collaborations in which outcomes are uncertain, individual contributions are hard to articulate, and the timing of outcomes relate to many variables beyond the control of the faculty members going up for tenure or promotion in the future.

It is understandable that faculty members would steer clear of activities that would contribute to the stress of promotion and/or tenure or hinder their chances of success through delayed research productivity since such productivity, especially with regard to research, has been shown to be key in the tenure and promotion process (Greenbank, 2006; Greene et al., 2008; Gubitosi, 1996; Terpstra & Honoree, 2009; Zabriskie, Dey & Riegle, 2002). Barriers to collaboration must be examined by institutions, mechanisms must be established that facilitate engagement in collaborative research, and the message must be communicated to schools, departments, and faculty members across the institution that collaborative research is an important and respected component of a researcher's portfolio.

The Importance of a Diverse Faculty. This study reinforced how important it is to institutions of higher education to have a diverse faculty. This has implications for the institutions themselves, as well as for national immigration policy and the agencies that support higher education's research efforts. Among the international faculty members interviewed, it became clear that they have a distinct advantage when it comes to collaboration with colleagues in their home country and regions. Personal connections and personally motivated travel provide

cost-effective opportunities to maintain and establish new connections with colleagues abroad. Their facility with local languages and cultures also provide them with ideal opportunities to collaborate with scholars who are incredibly skilled, but who do not speak English or understand U.S. institutions of higher education or their unique academic culture.

Advantages aside, however, international faculty also have unique disadvantages when it comes to collaborative research. Language issues related to English proficiency, publication bias against international authors, and cultural background can inhibit communication in collaborative initiatives and delay the outcomes of the research. By teaming up international faculty members with their U.S. colleagues, however, the research not only benefits from differing expertise and knowledge, but the U.S. faculty members' language facility and cultural familiarity can enhance access to colleagues within the institution, with other institutions inside the U.S., and at professional conferences within the U.S. context. The international partner on the other hand, brings his or her ties to bear in the research at hand. In short, by fostering diversity within the faculty, institutions are able to leverage the existing networks that each faculty member brings to the table. The more diverse the faculty is, the more unique weak ties there are likely to be.

The Power of Granting Agencies. It was also made abundantly clear in the interviews that granting agencies have enormous power in terms of facilitating or inhibiting collaborative research. Several faculty members spoke of their efforts to find collaborators in order to gain external funding for a project. These same interviewees, however, spoke of the difficulty they had in finding research collaborators due to conflicting incentives on the institutional side that emphasize the traditional lone-wolf approach to research. In order for granting agencies to

successfully encourage collaborative research, they may need to develop partnerships with the institutions themselves that go beyond the work of individual researchers. Such partnerships may involve the development of policies at the university level that give extra weight in promotion and tenure review to successful research projects that are both collaborative and supported by external funding. Just as overhead rates for facility use and maintenance, as well as cost share rates are negotiated in advance between many federal agencies and research institutions, similar mutual expectations and commitments with regard to institutional support for collaborative research could be established in advance. For example, universities might establish programs designed to help their faculty members become more competitive at a national funding level by providing the seed funding researchers need to build their research networks, develop collaborative projects, and engage in the pilot efforts needed to establish project feasibility.

Beyond the conflict between the academy's emphasis on independently produced research and funders' emphasis on collaborative scholarship, granting agencies were found to engage in a number of practices that inhibit research collaboration. The limited time window, for example, was cited by several faculty members as limiting the extent to which researchers engaged each other in the performance of research on a funded project. In one example, the grant period was so short that the researchers simply had to split tasks up and work on the components independently to complete the project on time. As a result, the researchers never really worked together, despite the fact that they shared funding for the project from a single agency.

Such evidence suggests that agencies should reconsider the grant periods that they have established for grants and take a particular project's needs and expectations into account, rather than a particular funding cycle that cannot take the actual research or the nature of the problem (or the steps needed to address the problem) into consideration. It may also be necessary to

implement more flexible funding time periods to accommodate unanticipated barriers and delays related to collaborative research. Because of strict time constraints, several faculty members reported being unable to adapt to new challenges posed by the research. A great deal of anxiety was associated with this and faculty members feared the longer-term funding and career consequences of not being able to successfully complete a project prior to a grant's end date.

In a related fashion, several faculty members spoke of the difficulty they had experienced on multinational collaborative projects where multiple funding sources with different time frames were also involved. Because of a lack of coordination between agencies, the production and reporting time frame for one group of researchers could be very different than that for a team working on a complementary area of research related to the project. For projects that require a particular sequencing of activities or efforts, this can create many problems, especially if the funding period for the last stage of the research is shorter than the period of the earlier stages of the research. By maintaining more flexible time periods that can accommodate the realities of the research and the unique constraints posed by other agencies also supporting the research, agencies would be able to enhance access to their funding sources and select projects more on the basis of merit rather than on the timing feasibility.

Finally, several faculty members spoke of the risk-averse nature of agencies, virtually requiring researchers to have done the project and proven its feasibility before they will consider the provision of funding. This puts researchers in a difficult position and hampers the pursuit of novel and innovate collaborate projects that are truly exploratory in nature. Granting agencies might consider the development of more diverse funding options in their portfolios so that seed funding is available to assess the feasibility of new and unproven projects. These small grants

might include provisions that allow for competitive access to larger grants if the pilot phase of the research proves successful.

Overall, faculty members' perceptions of the agencies supporting innovative collaborative research are that they are too rigid and rely too heavily on more traditional models of independently produced research. By creating new funding opportunities, engaging with universities directly, and becoming more flexible in terms of the timing and reporting expectations, agencies could use their funding to enhance the prevalence of collaborative scholarship and push the boundaries of science.

Study Limitations and Directions for Future Research

In addition to the methodological limitations articulated in Chapter 3, this study had several more general limitations that lead to important areas that would benefit from future research. A primary limitation of this study was the 2006 Survey of Doctorate Recipients itself. While this survey asked respondents to indicate whether or not they collaborated at each of the four levels of collaboration studied, these were the only collaboration-specific questions on the SDR. This necessarily limits our understanding of collaboration and how we can interpret the data that are there. Frequency data and an exploration of how well survey-reported factors predict different forms of collaboration do not help us understand how respondents define collaboration. Furthermore, the predictive factors that were examined could only include variables from a survey whose main purpose was only tangentially related to collaboration at best.

Due to the nature of scientific research today (Howard, 2011; NSF, 2011), interview data that suggest faculty members are nearly all collaborating on all four levels studied, and the

importance of the role of collaborative research engagement to scientific research production and the acquisition of external funding (Eddy, 2010; Kezar & Lester, 2009), a national longitudinal study examining patterns of, motivations for, and outcomes of collaborative research is called for. Such a survey could provide us with a better understanding of when people are collaborating, who they are collaborating with at different levels, how much they are collaborating, the cumulative effects of collaboration over time, and how collaboration affects their efforts to obtain financial support for their research.

Another area of future study would be to examine how early collaboration experiences affect respondents' career decisions. As was previously discussed, all faculty members interviewed reported having a collaborative research experience prior to beginning their postdoctoral research positions or faculty careers. What we do not know from this is how the absence of such early experiences with collaboration affects later career decisions. It is possible, for example, that without collaborative research experiences at the undergraduate or graduate level, students are less likely to pursue faculty or other scientific research careers in the future. Neither phase of this study was able to examine this question since both phases looked only at early-career faculty members.

Finally, for the qualitative phase of this research, faculty members from only one institution were interviewed. While it is difficult and rarely advisable to generalize results from qualitative research involving such limited sample sizes, by extending the interviews to more institutions and to different institutional types, a more rigorous examination of the results would be possible. For the present study, for example, it is impossible to rule out the impact of a unique institutional culture, set of policies, or precedents on faculty members' collaboration practices. Results from the quantitative phase of the study suggest that institutional type has significant

predictive power as it relates to collaborative engagement. Procedures related to tenure and promotion, for example, may be unique to the institution and affect faculty members in unique ways. Similarly, an institution's broader reputation in the academy and its ability to attract talent and resources may affect the collaborative opportunities of its faculty. By including more institutions, it may be possible to examine the roles of different policy choices, educational approaches, criteria for promotion and tenure, and resource allocation strategies in promoting a culture of scientific collaboration.

Concluding Thoughts

This study has examined collaboration among early-career faculty members from the perspective of national data, as well as from the perspective of individual faculty members at a single public university. The results of the two phases of the study support those who argue that collaboration is rapidly growing in its importance in the lives of today's researchers (Eddy, 2010; Kezar & Lester, 2009; Koschmann, Lewis, & Isbell, 2011; NSF, 2011; Ribes & Bowker, 2011). As local, national, and global knowledge hubs continue to exist, scientific expertise and knowledge continue to deepen and expand, and the sharing of knowledge across all types of institutional and political boundaries becomes increasing essential to researchers striving to produce responsible, informed, and ground-breaking research, we simply must know more about how we can act to train and enable scientists to become effective and successful collaborative researchers (Eddy, 2010; Kezar & Lester, 2009).

The training of researchers to be effective collaborators, and the incentives and support mechanisms needed to maintain collaborative engagement require an informed and multifaceted approach (Kezar & Lester, 2009). The responsibility for enacting this approach must be broadly

shared. Institutions of higher education, for their part, must work to ensure that undergraduates, graduates, postdoctoral researchers, and faculty members alike receive the training, mentoring, resources, and opportunities to pursue research collaborations. Graduation requirements, postdoctoral researcher performance expectations, as well as expectations for the promotion and tenure of faculty members could be better aligned to emphasize and support collaborative practice.

Agencies on the other hand, must develop the programs, policies, practices, and lines of communication needed to foster and further enable innovative collaborations, rather than hinder them. As the funders of much of the research occurring at institutions of higher education, agencies should partner more with universities to develop a set of more synergistic and complementary programs that enhance the power and potential of collaborative research. It is hoped that this dissertation serves as a motivator to institutions of higher education and agencies supporting higher education research to develop the mechanisms needed to achieve these important ends.

Finally, this study provides strong support for the use of social network theory's strength of weak ties hypothesis in developing our understanding of how collaborative processes work and are maintained. Developing this understanding is increasingly critical as our knowledge base deepens, our research communities expand and become more diverse, and our research questions become more complex. Collegial networks, both physical and virtual are the key to bringing in information from pertinent knowledge hubs and applying it in innovative ways to the questions that attract our imagination.

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Appendix 1: **INFORMED CONSENT STATEMENT**

The Department of Educational Leadership and Policy Studies at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You should be aware that even if you agree to participate, you are free to withdraw at any time without penalty.

Project Name

The Development of Collegial Networks Among Early-Career Faculty Researchers in the Science, Engineering and Health Disciplines

Project Overview

The purpose of this study is to examine how and when early-career faculty members in the Science, Engineering, and Health disciplines develop and utilize collaborative networks in their faculty careers. The reasons for these collaborations, the types of collaborative activity most engaged in, and how these collaborative relationships are maintained will be explored.

This study will consist of a single 45-70-minute open-ended interview that explores your experiences and perspectives as a collaborative researcher. Interviews will be recorded and the investigator may also take notes. Recordings will be stored as password-protected files on an external hard drive and notes will be stored in a locked file cabinet.

There are no anticipated risks associated with this project. The benefits to participation are indirect in that your responses may help inform administrators and academic departments as they develop policies, programs, and services designed to promote and support collaborative research among the doctoral, postdoctoral, and faculty research population working in the Science, Engineering, and Health disciplines.

Your name will not be associated in any way with your responses to the interview questions. The investigator will use a study number or a pseudonym instead of your name. The investigator will not share information about you unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this evaluation at any time in the future. Your participation in this study is entirely voluntary.

You are not required to sign this Informed Consent Statement and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

You may withdraw your consent to participate in this evaluation at any time. You also have the right to cancel your permission to use and disclose information collected about you, in writing, at any time, by sending your written request to: Dr. Susan Twombly, School of Education, Department of Educational Leadership and Policy Studies. If you cancel permission to use your information, the evaluators will stop collecting additional information about you. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

If you would like additional information concerning this study before or after it is complete, please feel free to contact me by phone or mail.

Participant Certification

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the evaluation and the use and disclosure of information about me for the evaluation. I understand that if I have any questions about my rights as a research participant I may contact the Human Subjects Committee Lawrence Campus (HSCL) office at 864-7429 or 864-7385 or write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7563, email mdenning@ku.edu.

I agree to take part in this evaluation as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_____ _____

Type/Print Participant's Name Date

_____

Participant's Signature

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Appendix 2: INTERVIEW PROTOCOL

Topic 1: *What forms of collaboration are participants engaged in with regard to their research activities?*

- Please describe who you collaborate with in your research activities.

Topic 2: *What are the mechanisms early-career faculty members employ in the development of their collaborative research networks, how are these networks maintained, and why are collaborations pursued?*

- What do you feel you gain from collaboration, and do these gains vary by type of collaboration?
- Are your collaborations professionally-driven, personally-driven, or a combination of the two?
- How do you decide who to collaborate with and when you need to collaborate?
- Does your choice of collaborator type differ according to the outcome goal of the research project (e.g. article, conference presentation, patent, book)?
- How do you gain timely access to resource people?
- How do you gain reciprocity and willingness to collaborate?
- Is your collaborative activity mutual, or one-sided?

Topic 3: *What is the perceived relationship between the collaborative work done in graduate school, the postdoctoral research period (if applicable), and the respondents' faculty careers?*

- In thinking about your development as a research scholar, what experiences contributed most to your development as a collaborative researcher?
- When and what was your first research-related collaborative experience?
- If you were to rank order the importance of the following training and mentoring experiences in your development as a collaborative researcher and your involvement in collegial networks, how would you rank them and why: doctoral studies, postdoctoral training, experience as a faculty member?

Topic 4: *Do faculty members with international status and domestic status differ in how they perceive the constraints on and opportunities available to them as they relate to the development of collaborative partnerships?*

- How do you feel that your status as a U.S. citizen / Non-U.S. citizen facilitates or constrains your collaborative activities? Does this differ by type of collaborative activity?

- Does your citizenship status affect the type of collaborative activities that you engage in? How so or why not?

- How do you think your colleagues with a different citizenship status are enabled or constrained by that status in their collaborative activities?