FACTORS INFLUENCING INTERDISCIPLINARY RESEARCH COLLABORATIONS

By

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ABSTRACT

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Research collaborations are an effective and necessary way to marshal resources and address complex, specialized problems. The U.S. federal government spends billions annually to fund research, much of which is directed toward research centers or teams (National Institutes of Health, 2012; National Science Foundation [NSF], 2014a). That level of investment, both by researchers and funders, demonstrates significant confidence that collaborations will be successful yet research suggests many collaborations can be frustrating with many groups underachieving or failing altogether (Kezar, 2005; Rhoten, 2004). This study used a qualitative, multiple case study approach to examine factors influencing combined STEM/social science interdisciplinary research collaborations. Fifteen members of three different research groups participated in two rounds of interviews at Bridgetown State University – a large, Midwestern research institution. Findings suggest there are institutional/external, group, and individual level inputs/antecedents to, and potential outcomes from, interdisciplinary collaborations. Emerging from this study is the Model of Factors Influencing Interdisciplinary Research Collaborations (MFIIRC). The study has theoretical and practical implications and has highlighted a number of areas for further investigation. Limitations of this research include a dearth of female principal investigators willing/available to participate in the study and a lack of racial/ethnic diversity among participants.

To researchers everywhere, especially the participants in my study, who are working hard to make the world a better place.

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CHAPTER ONE: INTRODUCTION

Research collaborations are an effective and necessary way to marshal resources and address complex, specialized problems. There are different investments of time and resources involved in research collaborations than when investigators work individually. Additionally, the U.S. federal government spends billions annually to fund research, much of which is directed toward research centers or teams (National Institutes of Health, 2012; National Science Foundation [NSF], 2014a). That level of investment, both by researchers and funders, demonstrates significant confidence that collaborations will be successful yet research suggests many collaborations are "too frequently a source of aggravation for individual members, leading to wasted time and feelings of discouragement" (Barron, 2003, p. 308). Further, many groups underachieve or fail altogether (Kezar, 2005; Rhoten, 2004).

The current research study used a multiple case-study approach to examine factors influencing STEM/social science interdisciplinary research collaborations with the goal of expanding understanding of what contributes to the success of research groups. In this chapter, I provide an operational definition of collaboration and then elaborate on the research problem by illustrating the context of, and rationale for the study. Next, I introduce the theoretical framework and finally, I discuss the research questions guiding the study.

Defining Collaboration

Myriad terms are used within the literature both to describe and allude to collaboration. Interdisciplinary, transdisciplinary, multidisciplinary, cross-disciplinary, partnerships, and collaboratives are commonly used and assume or imply collaboration (Eddy, 2010; National Academy of Sciences, National Academy of Engineering, & Institute of Medicine of the National Academies, 2004). As such, and in keeping with the literature, when the terms *partnership, interdisciplinary, multi-disciplinary, transdisciplinary, cross-disciplinary, inter- or*

multi-institutional, *multi-unit*, or *cross-unit* are used in this study, they represent umbrella terms to imply collaboration and to describe a specific situation (e.g., work across multiple disciplines). The term collaboration in this study, however, is used only to describe an instance of collaboration and does not imply additional circumstances (e.g., multiple disciplines, cross-institutional work).

Collaboration is ambiguous and difficult to define (Katz & Martin, 1997; Aboelela et al., 2007), and any study exploring the dynamics of collaborations first needs to operationalize the term within the context of the research. After reviewing many definitions for collaboration, I found Katz and Martin and Aboelela et al.'s assertions were accurate; there are multiple definitions of collaboration and each has a different meaning. For the purposes of the current study, I employed components of each of the definitions of collaboration from Bronstein (2003) and Amey and Brown (2004).

Bronstein (2003) defined interdisciplinary collaboration as "an effective interpersonal process that facilitates the achievement of goals that cannot be reached when individual professionals act on their own" (p. 299). Amey and Brown (2004) wrote interdisciplinary collaboration is "a group of faculty and staff from various disciplinary backgrounds (paradigms), often within a single university, organized to address a predetermined task" (p. 2). Both definitions offer components used to create the following operational definition: interdisciplinary collaboration is the process of people from different disciplines working together to create something that could not otherwise have been produced through their individual efforts alone.

Absent from my definition is the term *effective interpersonal* used by Bronstein (2003) because I did not want to make an evaluation of the collaboration process explicit within its definition. The word effective is subjective and I believe people within a collaboration will have

varying opinions about the effectiveness of the group. For example, a team may achieve the goal of having its paper accepted for publication but simultaneously be suffering from group-wide conflict and fractured relationships. In that case, I am not certain the collaboration could actually be considered an effective interpersonal process. For my definition, I chose the word create to reflect research that suggests collaboration is more than an additive process, rather it is one where new knowledge is created (Amey & Brown, 2004; Pavangadkar, 2012). Finally, I selected the word produce to imply the creation of something that did not exist before the team came together. I avoided using terms like meeting an objective or target because it is possible to be productive yet not achieve a predetermined goal and I wanted to honor that phenomenon.

Background of the Problem and Rationale for the Study

Given the complexity of many problems investigators are challenged by (e.g., modeling complex natural processes), collaborative research is necessary (Beaver, 2001; Creamer & Lattuca, 2005; Wray, 2002). Additionally, increasing specialization within fields and the expense of necessary resources makes it improbable that researchers can address many issues on their own (Beaver, 2001; Wray, 2002). "The fields have reached the point where we can't go any further being just biologists and we can't go any further being just computer scientists. We have to work together to come up with new knowledge" (Covert, 2012 in Pavangadkar, 2012, 4:14). The preceding statement, from a researcher working within an NSF-funded science and technology center (STC), illustrates the state of many science, technology, engineering, and math (STEM) fields today. In some fields, much of the discipline-specific information is known and to advance problem-solving ability, basic research at the edge of, and across disciplines is critical.

Salter and Martin (2001) undertook a critical review of the literature to understand the economic benefit of spending "considerable government funds…on basic research in universities" (p. 509). They concluded there is indeed return on investment and outlined six

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benefits to funding basic research: (a) a source of new knowledge; (b) new instruments and methods are discovered; (c) skill development for researchers, especially graduate students; (d) access to national/international networks of experts and information participation in basic research is important; (e) basic research is helpful in solving complex problems; and (f) basic research can spur "spin off" (p. 527) companies where knowledge and technology is transferred to a commercial/corporate sphere (Salter & Martin, 2001). Further, Salter and Martin argued for societal support of funding research because, "publicly funded basic research should be viewed as a source of new ideas, opportunities, methods, and most importantly trained problem-solvers. Hence, support for basic research should be seen as an investment in a society's learning capabilities" (p. 528).

Beyond being necessary, evidence suggests collaborations can be advantageous as compared to individual work. Collaborations produce publications more frequently (Baldwin & Austin, 1995; Franceschet & Costantini, 2010), more quickly (Lattuca & Creamer, 2005), produce better quality work (Boyer, 1990; Beaver, 2001), and can be more innovative (Amey & Brown, 2004; Clark, 2009; Sawyer, 2007; Surowiecki, 2004) than researchers working individually. Graduate students also benefit from working on research collaborations not only through knowledge acquisition and skill development, but also from a network development perspective and through socialization into the scientific community (Beaver, 2001; Katz & Martin, 1997; Moody, 2004; Salter & Martin, 2001; Wray, 2002)

Given the many benefits of collaboration and the significant investment of both human and financial resources, knowing that many collaborations fail to achieve their objectives (Kezar, 2005; Rhoten, 2004) is alarming. Collaborations can be fraught with communication difficulties (Bracken, 2005; Cummings & Kiesler, 2005), problems stemming from hierarchical differences

(Perry, Madden, Farrell-Cole & Amey, 2012), and unclear expectations around publication and ownership of intellectual property or other tangible outcomes (Cummings & Kiesler, 2005; Ledford, 2008). Additionally, there are geographic challenges that dispersed collaborations must deal with and that communication technologies cannot always overcome (Boschma, 2005; Perry et al., 2012; Rhoten, 2003). Bringing together researchers from different fields can be a challenge (Amey & Brown, 2004; Butler, 2011), and there are often issues when people from multiple institutions, even within the same field, attempt to collaborate (Cummings & Kiesler, 2005). Also, collaborations are influenced by the nature of the relationships between the researchers (Baldwin & Austin, 2005; Creamer, 2001; Cummings & Kiesler, 2005) and, like any relationship, research collaborations can be fraught with interpersonal problems.

Rationale for the Study

For fiscal year 2015, the NSF budget request to Congress was $7.255 billion (NSF, 2014a) and much of the Foundation's resources are directed toward funding research and specifically supports collaborations or research centers (NSF, 2014a). In addition, universities also support research via human resources, space, equipment, travel, and other costs. Given that NSF and other national funding agencies, along with higher education institutions, are supported by public money, there is a fiduciary responsibility to understand how collaborations can best be supported. Consequences of failed collaborations are significant and include wasted time and resources (Cummings & Kiesler, 2005), threats to tenure and promotion resulting from fruitless research (Beaver, 2001), and damaged relationships, tarnished reputations, fractured professional networks, and lawsuits (Ledford, 2008) have all resulted from unsuccessful collaborations.

Although a number of problems within collaborations can be avoided through comprehensive pre-planning (Cummings & Kiesler, 2005), issues still persist. Desire alone is insufficient to sustain collaborations. Given the myriad risks threatening to undermine their

success, along with the serious personal and financial consequences of their failure, working to understand factors influencing collaborations, in order to inform and support research groups, is important.

Introduction to Theoretical Framework

The theoretical framework for the current study is the Model of Factors Influencing Research Collaborations, which is based on research conducted by Rhoten (2003; 2004). Rhoten studied NSF-funded STCs in the environmental research and education portfolio and developed a model to illustrate where institutions fail to support research collaborations. Rhoten used her model to demonstrate that universities have not transitioned to an environment of interdisciplinarity. She argued interdisciplinarity does not lack *external attention* by funding agencies, for example, nor does it suffer from a lack of *intrinsic motivation* from researchers themselves. Rather, Rhoten suggested there is a lack of *systemic implementation* (e.g., university management, structures), resulting in collaborations accomplishing "far less than they could, or should, have" (p. 6).

Rhoten (2004) asserted previous researchers may have "overstated" (p. 6) the influence of external and intrinsic factors while underestimating "the broader set and deeper source of organizational misalignments" (p. 6). Her model, therefore, was intended to illustrate where universities could focus their attention in moving away from "piecemeal, incoherent, catch-as-catch-can" (p. 6) efforts in order to support a transition to interdisciplinarity where cross-boundary work is a norm and can be done seamlessly. Rhoten's data suggested institutions often use the label *interdisciplinary* (e.g., on a new department or a center) without changing underlying structures or functions. As such, systems that penalized (even unintentionally) cross-disciplinary collaboration (e.g., tenure and promotion policies), continued to do so resulting in

institutions having created expectations for, and invested resources in, initiatives that were "inherently incapable of achieving the very goals they [sought] to accomplish" (p. 9).

Using Rhoten's (2004) model as a framework, Perry et al. (2012) conducted research on an NSF-funded science and technology center (STC) – the Bio/computational Evolution in Action CONsortium (BEACON). Data from surveys, focus groups, and interviews with department chairs, faculty, postdocs, and graduate students affiliated with BEACON confirmed a number of findings within the literature and fit well within the context of Rhoten's model. As a result of the BEACON study, Perry et al. (2012) modified Rhoten's original model by expanding the systemic implementation portion to illustrate factors affecting collaborators within BEACON. The Perry et al. version (Figure 2) is the Model of Factors Influencing Research Collaborations (MFIRC).

The MFIRC illustrates three major clusters of factors influencing research collaborations: external attention, systemic implementation, and intrinsic motivation. An example of external attention is funding, which is an external factor because it lies outside the influence of the collaborators and is often a driving factor to engage in research (Rhoten, 2004). Other examples of external attention include policies, policy makers, government agencies, and associations each of which, during Rhoten's study, called for increased interdisciplinary research. Rhoten suggested intrinsic motivation is the internal drive (e.g., curiosity, passion) compelling researchers to engage in interdisciplinary projects. Rhoten characterized systemic implementation as those factors, neither external to the group nor internal to the researchers themselves (e.g., university management, structures) that influence research collaborations. Rhoten's original model did not define specific systemic implementation factors aside from giving the examples of *university management* and *structures*. After findings pointed to a

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number of discrete factors, Perry et al. (2012) updated Rhoten's model to illustrate both social

and organizational dimensions of systemic implementation. Within the systemic implementation

portion of the model exist a number of sub-factors all of which are influenced by social and

organizational elements. In Chapter Two, I provide a detailed description of each sub-factor and

contextualize them within extant literature but for now, an exemplar may prove helpful. An

example of a systemic implementation factor influencing collaboration that has both social and

organizational elements is technology. Videoconference technology – its availability, and ease of

use falls into the organizational realm whereas its application in connecting researchers across

the country falls into the social realm.

In the MFIRC, two arrows, representing social and organizational factors, characterize

the systemic implementation portion of the model. The arrows encircle a list of five sub-factors

and illustrate that each of the sub-factors is influenced by both social and organizational

elements. When developing the systemic implementation portion of the model, Perry et al.

(2012) realized there was a spectrum on which each of the sub-factors fell; at one end of the

continuum were social elements and on the other were organizational elements. Social elements

are those factors that influence and are influenced by human interaction. Organizational elements

are any other non-social systemic implementation factors that could influence the sub-factors

(Perry et al., 2012). Perry et al. chose to represent the social and organizational elements as

arrows to illustrate their dynamic influence over the sub-factors.

Research Question

The purpose of this research was to examine the systemic implementation portion of the

MFIRC (Perry et al., 2012) to determine if it accurately describes research collaborations outside

of STCs. Selecting non-STC research collaborations was intentional and important because the

model was created, then modified, based largely on studies of NSF-funded STCs. Centers are

composed of small collaborative groups so I wanted to focus on individual teams rather than a center as a whole. Also, social science collaborations benefit and suffer from a number of the same factors influencing their STEM colleagues (Baldwin & Austin, 2005), which suggests the need to examine the MFIRC across different types of collaborations. Collaborations within the humanities were not included in the current study because, although research collaboration is increasing in the humanities (Capaldi, 2009), scholars in the humanities often work individually (Beaver, 2001). Additionally, there is sometimes no financial incentive for humanities scholars to work together (Beaver, 2001) and given funding is a key piece of the MFIRC, applying the model to those types of collaborations, was inappropriate. When grants require it, humanities scholars have demonstrated willingness to collaborate (Kezar, 2005) but often their funding comes from private foundations (Atkinson & Blanpied, 2007) and the focus of the current study is on fields receiving significant federal dollars. In sum, research in humanities fields is different enough from science and social science in terms of norms and funding as to warrant their exclusion from the current study.

Focusing on systemic implementation portion was intentional because there seemed to be many factors at play within that section of the model. Although external attention factors like funding and policies are dynamic and fluctuate as leadership changes, they are entities known to influence collaborations in a somewhat predictable way. For example, if funding shrinks, budget cuts or non-renewal of contracts could be expected. Situating the study at one institution allowed me to begin the project with external attention viewed more as a contextual element than a primary variable. Like external attention, intrinsic motivation played a contextual role in the current study. Although levels of intrinsic motivation vary across individuals, I made no attempt to quantify them because I did not set out to conduct a motivation study.

The systemic implementation portion of the MFIRC is composed of a number of variables and Rhoten (2004), in designing her original model, argued a lack of systemic implementation was to blame for the failure or underperformance of many collaborative research projects. Perry et al. (2012) made a case for several discrete systemic implementation factors in the MFIRC, but questions remained about whether their assessment held and whether or not there may be additional variables influencing collaborations. The main research question driving this study was, how well does the MFIRC describe systemic implementation factors impacting investigators at a large, research university who are engaged in combined STEM/social science interdisciplinary collaborations?

Summary

In this chapter, I introduced the purpose and prevalence of research collaborations, highlighted their importance, and began to outline some of the complex factors influencing them. After making a case for the importance of studying research collaborations, I introduced the theoretical framework within which this study will be situated. The goal of contributing to extant literature and expanding knowledge about factors influencing research collaborations led me to the following research question: How well does the MFIRC describe systemic implementation factors influencing investigators at a large, research university who are engaged in STEM/social science research collaborations? Ideally findings from this study could inform researchers as they enter into collaborative relationships. In addition, findings might also be informative to decision-makers at the institutions where research collaborations are taking place.

In the next chapter I review relevant literature related not only to collaboration in general but also to factors known to impact collaborations and I expand on the description of the theoretical framework, the MFIRC.

CHAPTER TWO: LITERATURE REVIEW

This chapter provides a review of relevant literature and begins by discussing benefits of collaboration and illustrating the importance of collaborative research. Next, the theoretical framework is described in detail and I review literature related to each of its component parts. Throughout the chapter attention is paid to ways in which collaboration has previously been studied, which helps illustrate where the current study fits within the literature.

Benefits of Collaboration

A number of positive outcomes can be attributed to collaboration. Benefits influence one's field or discipline, one's career, students, and outside constituents such as government and citizens. This section describes some of the positive outcomes of research collaboration for the aforementioned stakeholders. The literature is grouped into three main subheadings: advancing knowledge and strengthening careers, benefits for students, and government/societal benefits.

Advancing knowledge and strengthening careers. This section reviews literature that describes how collaboration helps expand understandings within and across fields and, in addition, how collaboration plays a role in researcher development. People tend to be more innovative and make better decisions when they collaborate (Clark, 2009; Sawyer, 2007; Surowiecki, 2004). Accuracy is increased and feedback is received quickly when people are working together (Beaver, 2001). Collaborative work, especially in the sciences, tends to be published more frequently than individually authored work (Baldwin & Austin, 1995; Franceschet & Costantini, 2010). The higher rate of multi-authored versus single-authored papers reaching publication has been attributed to the increased quality of the work because multiple people contribute to its creation resulting in fewer errors, the ability to cross disciplinary boundaries, and the opportunity to see patterns across fields (Boyer, 1990; Beaver, 2001).

Beaver (2001) provided a comprehensive overview of the benefits of collaboration when he reflected on the past, present, and future of scientific research collaboration. According to Beaver, collaborations are advantageous because they increase efficiency, speed, and breadth of research. He suggested the "multiplicity of viewpoints energizes and excites participants," which "makes actual work more intense" (p. 369). Researchers embedded within specific social clusters think and interpret research in similar ways (Moody, 2004). Moody reviewed writings by Durkheim (1933), Mannheim (1936), and Kuhn (1970) who suggested people's "ideas are a function of position in a social setting, which is deeply structured by interaction patterns" (p. 215). Kuhn (as cited in Moody) "argued that belief in the empirical validity of theory could be sustained long past the available empirical evidence if scientists were embedded in research communities who systematically interpreted data in similar ways" (p. 215). In short, patterns of thinking can become impermeable to new ideas if researchers are not careful to include outside others or entertain fresh perspectives. Interdisciplinary collaboration is a way to bring together diverse approaches and new paradigms.

Atkinson and Blanpied (2007) argued that researchers competing for coveted and, in some cases, shrinking research funds are likely to propose safe projects rather than risky ones. The results, the authors suggested, are fewer scientific breakthroughs, more research that is "mediocre at best" (p. 19), and projects that contribute more to researchers' curriculum vitae than to advancing knowledge. A benefit to collaborative researchers is that investigators can pool resources and contribute to risky proposals while maintaining other, safer projects. A failed project that one is only partially invested in is less threatening to one's career than a failed project that involved all, or a significant portion, of one's resources. In the same way financial advisors recommend diversifying one's investment portfolio, collaboration can help researchers

be involved with a number of different projects and assume less overall risk. As Beaver (2001) suggested, collaboration helps researchers avoid having all their "eggs in one basket" (p. 369).

Wray (2002) argued epistemic goals could be met as a result of collaboration. He suggested scientists need to collaborate because the research requires access to "abundant resources" (p. 151) and those not participating in collaborations are excluded from the latest knowledge, important networks, and tools. In short, Wray argued, lone researchers cannot expect to stay relevant or advance their field unless they participate in some form of collaboration. Wray's assertion about the importance of networks is echoed throughout the literature (Abbasi, Hossain, & Leydesdorff, 2012; Eddy, 2010; Pavangadkar, 2012; Schiffauerova, 2008; Wagner & Leydesdorff, 2005).

Benefits for students. Graduate students, more so than undergraduates, are likely to be directly influenced by research collaboration. Graduate students often work with researchers on projects and in labs and therefore benefit not only from content knowledge and skill development but also from socialization into the scientific community (Beaver, 2001; Katz & Martin, 1997; Moody, 2004; Salter & Martin, 2001; Wray, 2002). Crane (1972) coined the term *invisible college* to describe networks of scientists who collaborated together regardless of geography or institutional affiliation. If one does not become socialized to collaboration in graduate school it is unlikely one will spontaneously begin collaborating early in one's faculty career where reward structures, in many cases, are not designed to support co-authored work (Kezar & Lester, 2009; Lattuca, 2001; Trower, 2008). Students who experience collaboration during their graduate training can begin to form their own networks that will become the future invisible colleges and help them sustain collaboration over time.

Government/societal benefits. The scope of problems faced by society is broadening and demands the use of innovative approaches in order to address them. As much as discipline-specific research is valuable, interdisciplinary research is increasingly important. Caruso and Rhoten (2001) said, "while monodisciplinary studies will continue to serve an irreplaceable function in both training researchers and conducting research, we face enormous problems in complex arenas such as globalization, the environment, human health and development, which monodisciplinary research is by definition unable to address."

Given the tremendous cost of scientific research, even with grant support, collaboration may be necessary in order to access the broad base of resources required to execute projects (Salter & Martin, 2001; Wray, 2002; Franceschet & Costantini, 2010). Salter and Martin undertook a critical review of the literature to understand the economic benefit of spending "considerable government funds…on basic research in universities" (p. 509). They concluded there is good return on investment and outlined numerous benefits to funding basic research including its utility in solving complex problems and the possibility for discovery and subsequent transfer of technology. Further, Salter and Martin argue for societal support of funding research because, "publicly funded basic research should be viewed as a source of new ideas, opportunities, methods, and most importantly trained problem-solvers. Hence, support for basic research should be seen as an investment in a society's learning capabilities" (p. 528). Collaboration and basic research are directly related to each other. Increasingly, basic research is being conducted at the boundaries of disciplines because much of what remains to be discovered does not fit neatly inside the margins of any particular field of study (Pavangadkar, 2012). Supporting basic research means supporting collaboration and given the benefits of basic

research, understanding how to sustain collaborations so they can be productive until their natural end, is important.

Detailed Description of the Theoretical Framework

To appreciate the structure and function of the MFIRC, understanding the theoretical underpinnings of its predecessor, Rhoten's (2004) model, will be helpful. This section describes how Rhoten's model came to be and elaborates on the reasons Perry et al. (2012) used and eventually modified it. Following that, each of the sections of the MFIRC are described and discussed in relation to extant literature.

Foundations of Rhoten's model. Rhoten's (2004) model (Figure 1) was developed following her NSF-funded study of interdisciplinary research networks. Prior to launching the NSF center study, Rhoten had conducted research about interdisciplinarity and had also written, with her colleague Denise Caruso of the Hybrid Vigor Institute, a white paper entitled *Lead, Follow, Get Out of the Way: Sidestepping the Barriers to Effective Practice of Interdisciplinarity* (Caruso & Rhoten, 2001). Caruso and Rhoten described and identified reasons for the major roadblocks faced by those who want to engage in interdisciplinary research:

> strong institutional bias against interdisciplinarity at most universities; the differences in defining and achieving success for an interdisciplinary v[ersus] a disciplinary endeavor; achieving consensus on a common problem or topic for study; establishing common understanding; access to cross-disciplinary data and publications; competition and the "geopolitics" of knowledge; the willingness to trust others outside of the home disciplines; publication requirements; and a commitment to shared resources and funding (p.2).

The authors also offered a "proposal for sidestepping these roadblocks, which allows researchers to choose from various levels of participation — to lead, follow, and/or simply observe" (p. 2). Caruso and Rhoten proposed a new way of conducting interdisciplinary research separated altogether from academic institutions which, they said, "is the best, and possibly the only effective way to sidestep some of the extant roadblocks of funding and turf battles" (p. 15).

Their proposal for institution-less research groups was based largely on the model of MacArthur Research Networks, which are funded by the MacArthur Foundation for projects organized around specific topics and are composed of researchers who are not affiliated with academic institutions. As such, researchers are funded directly by "[research] network administrators so there is no overhead charge or other direct financial benefit to the institution. Institutional bureaucracy as a roadblock to interdisciplinary work is completely sidestepped" (Caruso & Rhoten, 2001, p. 14). MacArthur Research Networks have been in existence since the 1980s and have been responsible for numerous important advances in knowledge (MacArthur Foundation, 2014). The MacArthur Research Network style, however useful, does not account for researchers who are drawn to work in a more traditional arena: the university. As such, understanding how to support researchers and dismantle barriers to interdisciplinarity remains important.

Rhoten's 2002 to 2003 study of NSF-funded STCs was a way to examine interdisciplinary research networks and methods. Her 2003 report to the NSF, *A Multi-Method Analysis of the Social and Technical Conditions for Interdisciplinary Collaboration*, did not evaluate the outcomes of research groups. Rather, her aim was to map the structure and social networks of the research groups and study the relationships and conditions influencing their work. From that extensive report came her 2004 article *Interdisciplinary Research: Trend or Transition* and the model upon which the current study was based. Rhoten's 2004 *Trend or Transition* article challenged institutions for their lack of organization to support interdisciplinarity despite strong external attention (e.g., funding for projects) and intrinsic motivation (i.e., desire on the part of researchers to engage in collaborative work). In addition to

her history of study and publication on interdisciplinarity, two major influences

Figure 1   Rhoten's Model

Figure 1 Rhoten's model illustrating various factors influencing research collaborations. From Rhoten, D. (2004). *Interdisciplinary research: Trend or transition.* Washington, DC: National Center for Atmospheric Research.
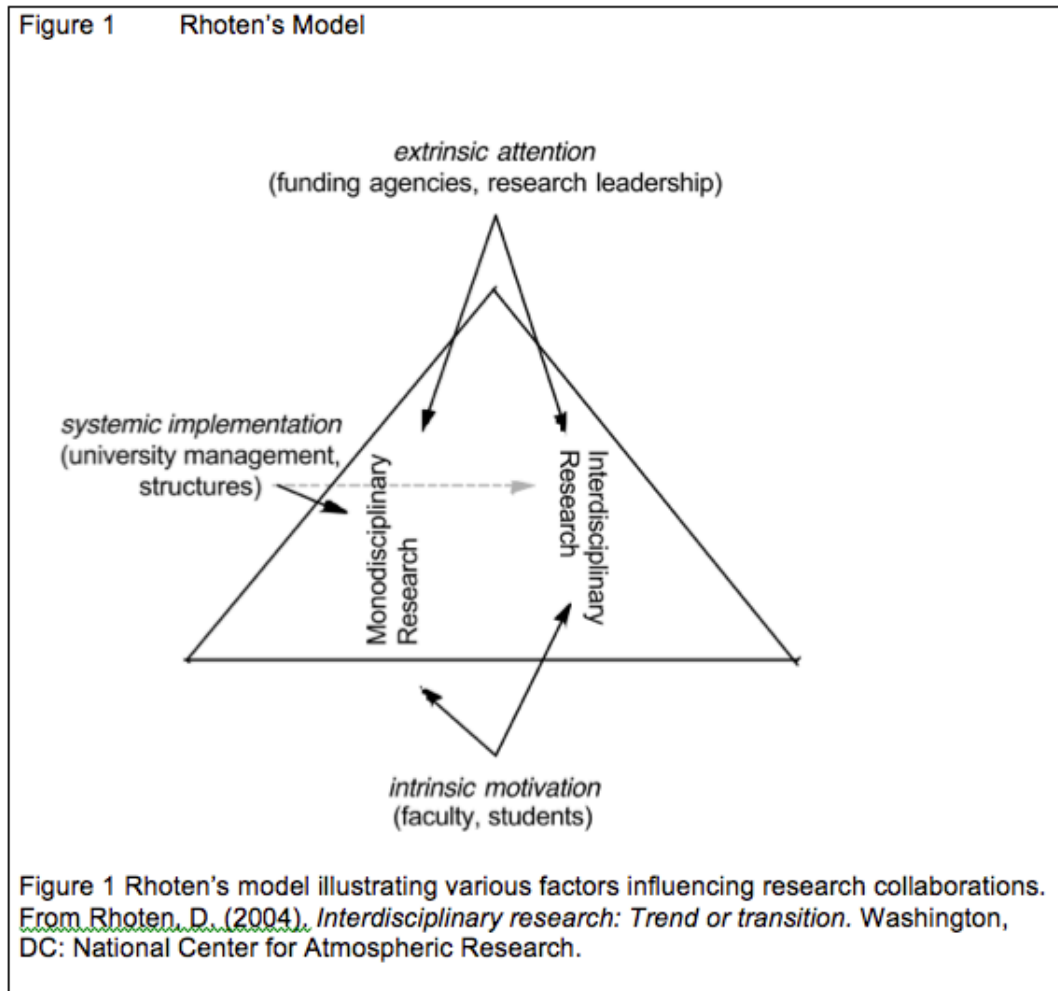
on Rhoten's (2004) work were Wilson's (1998) *Consilience: The Unity of Knowledge* and Huy

and Mintzberg's (2003) Change Triangle discussed in their article *The Rhythm of Change.*

According to Wilson, who was influenced by William Whewell's writing from the 1800s,

consilience is a "jumping together of knowledge by the linking of facts and fact-based theory

across disciplines to create a common groundwork of explanation" (Wilson, 1998, p. 8). Wilson

also suggested "the ongoing fragmentation of knowledge and resulting chaos in philosophy are

not reflections of the real world but artifacts of scholarship" (p. 8). Wilson was reflected in

Rhoten's (2004) work by the way she thought about, looked for, and critiqued systemic

implementation – the systems and structures within universities that could support, or form

barriers to, consilience.

While Rhoten (2004) emphasized the concept of consilience she was also considering the

ways universities operate and specifically, the way they change. Rhoten suggested institutions

have treated interdisciplinarity as a trend rather than a transition where universities have

relabeled existing entities rather than making substantial changes in structures, functions, or

policy. An example of this phenomenon would be calling an interdisciplinary group an

Interdisciplinary Institute and then not giving that group their own space or administrative

support. Most importantly, extant policies (e.g., tenure and promotion) would apply to people

working within the interdisciplinary institute in the same way they did when they worked in their

home departments which does not support true interdisciplinarity and instead, as Rhoten

suggested, allows the "persistence of old structures [that] created real or perceived disincentives

to and penalties for pursuing interdisciplinary work" (p. 9). Further, and as Rhoten argued, more

problematic:

> lack of systemic implementation taken in order to re-design and not just re-name these
> structures and thus actively support interdisciplinary research has actually created
> initiatives that are inherently incapable of achieving the very goals they seek to
> accomplish and unfortunately unable to serve the very constituents they hope to support
> (p. 9).

Seeing a need for opportunities for consilience, and understanding that systemic

implementation was key to making that happened, Rhoten modified Huy and Mintzberg's (2003)

Change Triangle to illustrate how she thought interdisciplinarity could best be supported. Huy

and Mintzberg created a model illustrating three types of change within higher education

institutions: *dramatic change* (top down), *organic change* (bottom up), and *systemic change*

(driven from "the middle"). Each of the types of change had an accompanying zone as labeled by

Huy and Mintzberg: dramatic change is in a *zone of revolution*, organic change is in a *zone of rejuvenation*, and systemic change is in a *zone of reform*. Huy and Mintzberg argued universities participate in each type of change with varying degrees of success and suggested systemic change "is slower, less ambitious, more focused, and more carefully constructed and sequenced than dramatic change" (p. 80). Although Huy and Mintzberg argued systemic change can be overly formalized and could stifle creativity, systemic change obviously appealed to Rhoten in terms of implementing interdisciplinarity at the institutional level because her model borrowed heavily from Huy and Mintzberg's.

The component parts of Rhoten's model. Rhoten likened external attention to dramatic change as discussed by Huy and Mintzberg. External attention, in Rhoten's model, comes from outside agencies (e.g., policy makers) or leaders and the effect can be a forced change (e.g., requiring interdisciplinary teams on grant applications). Huy and Mintzberg cautioned that some, though not all, dramatic (i.e., top down) change can be ineffective over the long term; Rhoten made a similar argument in that requiring interdisciplinarity without providing support structures would not help sustain collaboration. Organic, bottom up change as described by Huy and Mintzberg is generated among people working in the system. Similarly, Rhoten called bottom up attention to interdisciplinarity *intrinsic motivation* in her model. Both models illustrate that the "bottom of the triangle" is where one finds the majority of people doing the work of the organization. People represented by the bottom of the triangle are the ones likely to generate ideas based on practice but do not necessarily have the power to influence the implantation or sustainability of new initiatives. The middle of Huy and Mintzberg's and Rhoten's model is where authors suggest changes can be supported and sustained. The authors all argued for reform of systems, structures, and policies at the organizational level to ensure change is managed

carefully and supported over time. Rhoten specifically argued that neither funders and leaders, nor the researchers themselves can make interdisciplinarity a seamless part of an institution. Rather, the university itself must redesign structures and functions, system-wide, in order to support interdisciplinary work.

       Rhoten updated. In 2009, Dr. Patricia Farrell and Dr. Marilyn Amey were contracted to conduct the organizational evaluation of an NSF-funded STC - the Bio/computational Evolution in Action CONsortium (BEACON) Center, which is a consortium of five institutions: Michigan State University, North Carolina A&T University, University of Idaho, University of Texas at Austin, and University of Washington. Drs. Farrell and Amey, along with their graduate students, conducted a baseline study of BEACON, which focused on topics like the center's mission, leadership, and climate along with questions regarding what researchers were excited about, and anticipated being challenged by, in terms of their involvement with BEACON. During 2011, the evaluation team focused on two major areas: department chairs and factors influencing the center. The latter topic, factors influencing center development, became the research on which modifications of Rhoten's (2004) model were based. The following questions guided our 2011 evaluation efforts around center development: What factors affect early inter-institutional and interdisciplinary collaboration? How do these factors influence the early development of a central coordinating entity (BEACON)? Although we had a number of models of organizations, organizational development, and interdisciplinarity available to us, including one authored by Dr. Amey herself (Amey & Brown, 2004), we found Rhoten's (2004) model to be an appropriate framework around which to organize our thinking., The BEACON Center has ample external attention (i.e., $25 million from NSF over five years) and also ample intrinsic motivation (i.e., over 100 faculty, postdocs, and graduate students across many disciplines who had joined the

center). As such, we focused our attention on *systemic implementation* and looked to Rhoten,

along with the literature, to help us describe some of what we were seeing with participants in

our evaluation study. From 2009 through 2012 we administered not only the baseline survey but

also shorter, topic-specific surveys and hosted focus groups for graduate students and postdocs,

and conducted interviews with department chairs. By 2012 we had extensive and rich data upon

which to draw not only for our evaluation for BEACON leaders, but also for the purposes of

expanding knowledge about interdisciplinarity. From our data emerged details about the

structures within the systemic implementation portion of Rhoten's original model. To represent

our findings, we added sub-factors to the systemic implementation and presented the updated

version, the Model of Factors Influencing Research Collaborations (MFIRC), for feedback at a

national conference (Perry et al., 2012). The MFIRC is described in greater detail in the

following sections.

   The MFIRC in detail. There are three major sections to the MFIRC (Figure 2), external

attention, intrinsic motivation, and systemic implementation, and each has a category of sub-

factors influencing research collaboration.

Figure 2 Model of Factors Influencing Research Collaborations (MFIRC)
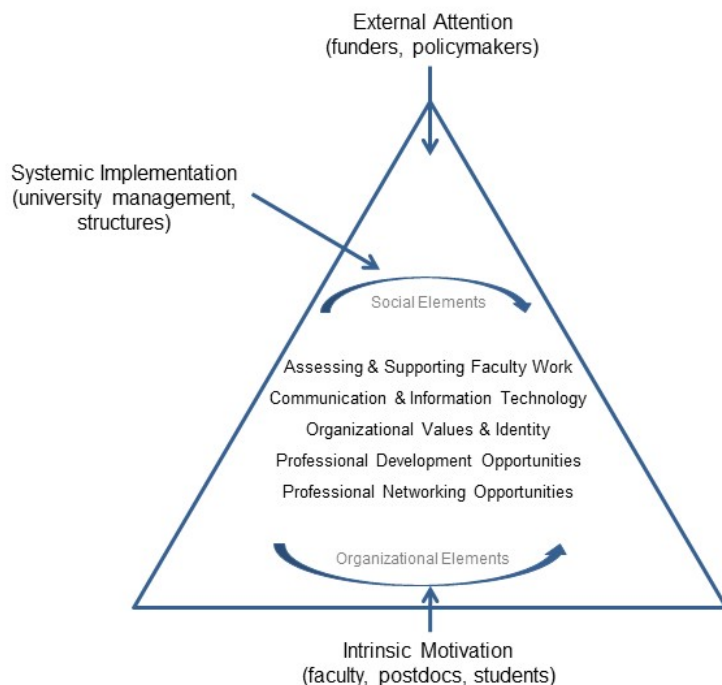
Figure 2 MFIRC from Perry, L. M., Madden, K., Farrell-Cole, P., & Amey, M. J. (November, 2012). *An Examination of Systemic Implementation Factors Influencing Research Collaborations.* Charlotte, NC: Association for the Study of Higher Education.

This section of the chapter provides a more in-depth description of the model but focuses mainly on the systemic implementation section. The MFIRC is an adaptation of Rhoten's (2004) model and offers an expanded description of systemic implementation factors Perry et al. (2012) found to be at work in their study of an NSF-funded science and technology center. Within the systemic implementation portion of the model are two major factors, *social* and *organizational*, and five sub-factors: *organizational values and identity, assessing and supporting faculty work, professional networking opportunities, professional development opportunities,* and *communication and information technology*. In the following sections, each major and sub-factor is described and contextualized within the literature.

External attention. External attention is the first of three major components of the MFIRC. Rhoten (2004) characterized external attention as powers outside of collaborations that influence the group. For example, government agencies such as NSF and NIH increasingly demand projects they fund be based on interdisciplinary work (NIH, 2014; NSF, 2014b). Similarly, some private foundations require collaboration as a condition of funding (Thorp & Goldstein, 2010). Professional associations and higher education institutions themselves have also recognized the benefits of interdisciplinary work and many have voiced their support for increasing this type of work (Rhoten, 2004). When funders' requests for proposals require interdisciplinary collaboration, researchers must decide between not applying for the grant or ensuring their work is multidisciplinary. Historically, tenure and promotion policies have not been equipped to evaluate in ways that recognize and reward collaboration (Kezar & Lester, 2009; Lattuca, 2001; Trower, 2008) so changes could benefit those seeking to engage in research partnerships. Institutions can influence researchers by altering tenure and promotion policies and rewards structures to support interdisciplinary collaboration. Beyond external attention, researchers are also motivated intrinsically to participate in interdisciplinary collaboration and the following section discusses reasons investigators engage in collaborative work.

Intrinsic motivation. Intrinsic motivation is the second of the three major portions of the MFIRC and, according to Rhoten (2004), is another factor driving researchers to enter into collaborative relationships. Rhoten's suggested faculty want to investigate problems outside the boundaries of their particular discipline and also because of a "shift in their epistemological values and intellectual interests" (p. 8-9). According to Sloan (1989), faculty who are intellectually stimulated in a way that "changes the way people think about the subject area" (p. 137) become intrinsically motivated. In terms of Sloan's assertion that collaboration helps to

change how people think about subjects, Amey and Brown (2004) made a similar claim: They suggested a hallmark and benefit of collaboration is that people come together to create new knowledge rather than just reconfigure existing understandings. Participants in Pavangadkar's (2012) video echoed both Sloan and Amey and Brown by confirming that the multiple disciplinary perspectives afforded by collaboration helped them to think about their work in novel ways. Fox & Faver (1984) and Sloan (1989) all suggested collaboration can help researchers avoid feelings of isolation. Melin (2000) studied 195 researchers involved in collaborations who reported feeling happy and excited about not only working on challenging research problems but also about their interactions with their collaborative colleagues.

Systemic implementation. Systemic implementation, the main focus of the current study, is the third of three major components to the MFIRC. Two major elements influencing collaboration comprise the systemic implementation portion of the model: organizational and social factors. Under the umbrella of social and organizational factors are five sub-factors that influence collaboration and are themselves influenced by social and organizational factors. The connection between each of the three major components (external attention, intrinsic motivation, and systemic implementation) and their sub-components are illustrated in the MFIRC (Figure 2). In the following sections, I review literature that explains the organizational and social elements of collaboration and then I provide descriptions of each of the five sub-factors and review literature related to them.

Organizational and social factors. Research collaborations are influenced by both organizational and social factors. Later in the chapter, each of the MFIRC systemic implementation sub-categories are described and within those, there are additional references to specific social and organizational elements at play. As such, this portion of the chapter focuses

more broadly and describes factors influencing collaboration such as one's field of study, formation and maintenance of research groups, and some challenges associated with collaborating.

Despite disciplinary differences in frequency, collaboration has been increasing steadily since World War II (Baldwin & Austin, 1995) and continues to be a trend (Beaver, 2001; Clark, 2009; Kezar, 2005; Kezar & Lester, 2009). Traditionally, researchers in applied fields have tended to collaborate more so than in those working in theoretical fields (Clark, 2009). Additionally, researchers working in mature fields (e.g., biology, physics) where paradigms are established or in fields where external financial support is available, tend to collaborate more than others (Baldwin & Austin, 1995; Pavangadkar, 2012).

By the mid-1990s, the metaphor of researcher as "lone-scholar" or "lone-wolf" (Baldwin & Austin, 1995, p. 47; Beaver & Rosen, 1979) had faded in many disciplines but in the humanities, scholars still tended to work independently often because there were few financial incentives for them to work collectively (Beaver, 2001). In the social sciences, where fewer complex pieces of equipment or laboratory techniques tend to be required, investigators are not as reliant on others to conduct their research and can therefore proceed individually (Clark, 2009). Additionally, some methodologies common in social sciences may be more difficult to conduct in a team and lend themselves to individual investigation (Clark, 2009).

Participating in collaboration can be difficult. Researchers can face obstacles with colleagues, resources, or within the organization that can constrain their participation in collaborative work (Austin & Baldwin, 1991; Kezar, 2005; Kezar & Lester, 2009; Beaver, 2001). Building networks of colleagues takes time and can be challenging but is critical if one hopes to collaborate (Moody, 2004). Once a network is established, from which a collaboration may

emerge, practical matters like area of focus, communication, and division of work must be decided (Baldwin & Austin, 1995). Working in groups is challenging in multiple ways and interpersonal problems are common (Miller & Brimicomb, 2004; Ledford, 2008; O'Rourke, Crowley, Eigenbrode, & Wulfhorst, 2014; Neumann, 2010). Given that faculty tend to affiliate more so with their disciplines than any other group, interdisciplinary collaborations can be sidelined by disciplinary conflict (Amey & Brown, 2004) or simply not understanding each others' disciplinary language (Pavangadkar, 2012).

The MFIRC Sub-Factors

The MFIRC (Figure 2) features three main sections: external attention, intrinsic motivation, and systemic implementation. Within the systemic implementation portion of the model lie five sub-factors as identified by Perry et al. (2012) in their 2012 study of an NSF science and technology center: (a) organizational values and identity, (b) assessing and supporting faculty work, (c) professional networking opportunities, (d) professional development opportunities, and (e) communication and information technology. The term sub-factors refers to the fact that they are part of a larger category (systemic implementation) but are themselves discrete factors that were found to influence research collaboration. The following sections describe the sub-factors in detail, how they came to be represented within the MFIRC, and their context within extant literature.

Organizational values and identity. In their study of an NSF-funded STC, Perry et al. (2012) found participants discussed issues relating to identity and values of the center. The core group of scientists (BEACON leaders) who drafted the initial grant were clear about the goals of the center and their desire for collaborations to sustain themselves beyond the cycle of NSF funding. Messaging from BEACON leaders was consistent over two years "but it took time for goals, values, and a sense of collective identity to expand outward to participants across all roles

and institutions" (Perry et al. 2012, p. 13). Identifying with or feeling a sense of belonging to the group is important for collaborators involved with research centers because participants who have a difficult experience (e.g., interpersonal conflict, funding problems), may still participate in the center (Perry et al., 2012). Mentoring and outreach, or other non-research functions, "support the development of shared identity and values" (Farrell, Amey, Perry, & Madden, 2013, p. 6) and can further the goals of centers so it is important for group members to participate in these efforts (Farrell et al., 2013; Perry et al., 2012).

The literature shows evidence that researcher identity or sense of affiliation is tied more strongly to one's discipline than to one's institution (Miller & Brimicombe, 2004; Neumann, 2010). Similarly, evidence suggests faculty have difficulty identifying with emerging trans-disciplinary fields (Benbasat & Zmud, 2003). Disciplinary affiliation has the potential to hamper efforts to create cohesive collaborative interdisciplinary groups; "it's not a trivial thing to get past the way that people talk from different disciplines and the fact that you may use similar terms in very different ways" (Kerr, 2012 in Pavangadkar, 2012, 5:14). Similar to Kerr (2012), Barrick (2012 in Pavangadkar) said collaboration is about "figuring out ways to put people in the same room and sometimes that means struggling for a while and talking past each other" (5:26).

Perry et al. (2012) found organizational values and identity to be a factor impacting the development of the NSF-funded STC they studied in the way participants talked about feeling part of the center even when they had not received funding from it. Although organizational values and identity was a prominent theme in the Perry et al. research, the current study focused on smaller, individual collaborations rather than an entire research center. In the present study, the group of people within a research collaboration served as the organization and questions

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designed to understand the importance or influence of the groups' organizational values and identity were written into the interview protocol (Appendix A).

Assessing and supporting faculty work. This section highlights mismatches between tenure and promotion policies and characteristics of collaborations by discussing the evaluation of scholarly work, author order on publications, and time spent on research projects. Untenured faculty may be hesitant to collaborate because they believe tenure and promotion committees will not assess the candidate's work in a positive manner (Hurtado & Sharkness, 2008; Lattuca 2001). Research suggests faculty fears are not unfounded; despite the known benefits of collaboration, many fields have yet to enact standard methods for evaluating outcomes and assessing the scholarly merit of work produced through collaborations (Lattuca, 2001; Moody, 2004; Trower, 2008). Typically scholars are judged based on their individual contribution to the field. When researchers devote much of their time to collaborative projects, their work can be judged unfavorably by tenure and promotion committees who may not appreciate the significance of the candidate's contribution (Hurtado & Sharkness, 2008; Lattuca, 2001).

Author order on publications is an important issue for faculty. Tenure and promotion committees want to see candidates publish in credible outlets and ideally, as primary author. When collaborations result in publications, there can be a large number of authors and names can be buried within a long list. Tenure and promotion committees at institutions where the culture does not support or reward collaborative work can devalue the scholarly contribution of the candidate (Kezar, 2005) whose name does not appear first among a list of authors. Further, and this is an issue the scientific community has grappled with for decades, people can be named on papers regardless of their level of contribution; someone performing a routine part of an experiment or who loaned equipment can receive the same level of credit as a person who made

critical contributions to the project (Stokes & Hartley, 1989; Lee & Bozeman, 2005). As such, it is incumbent upon candidates to make their project contributions clear when they prepare their promotion and tenure dossiers. Similarly, tenure and promotion committees should be aware of how collaborative research norms can be different from practices common for individual inquiry.

Collaboration can sometimes lengthen the time research projects take and specific types of inquiry, for example community based participatory research, involves multiple stakeholders (e.g., researchers, policy makers, community agencies and their clients) and can require years to establish relationships (Israel et al., 2006). Faculty members facing the strict timeline in which to achieve tenure, may not have the luxury of choosing this type of research, which means pressing problems may go unaddressed. Trower (2008) suggested extending the current six-year probationary period by five or more years to create opportunities for faculty to undertake complex, non-traditional, or lengthy projects they may otherwise not.

Professional networking opportunities. Professional networks are critical to success in a number of fields and especially within STEM (Clark, 2009; Melin, 2000; Salter & Martin, 2001). Professional networks beget collaborations and collaborations can expand people's professional networks. People embedded in professional networks (e.g., tenured faculty) should introduce newer researchers (e.g., graduate students, postdocs, untenured faculty) to others within their network. Interdisciplinary research centers, smaller research collaborations, and professional associations provide excellent opportunities for people to engage with each other when they would not otherwise have the opportunity to meet.

Researchers not associated with a network also bear responsibility to become integrated (Melin, 2000), but getting integrated in a meaningful way can be challenging. Merely being in proximity to one another, at a conference for example, does not guarantee people will meet or

connect in a productive way; intentional relationship building needs to take place. Perry et al. (2012) found their participants (members of a geographically dispersed, NSF-funded STC) consistently indicated a desire for in-person interactions despite there being sophisticated communication technologies at their disposal. Even when in-person interaction did take place (e.g., STC annual meeting) many of Perry et al.'s participants, particularly graduate students and postdocs, worried about meeting the "right" people - those with whom they could form collaborative relationships. Melin (2000) studied 195 research collaborators and stated, "there has to be a distinction between fruitful chats over coffee and systematized collaboration with publications as one result" (p. 33).

Professional development opportunities. Some research suggests facilitating the professional development of others is actually a motivation for faculty becoming involved in research collaborations (Lee & Bozeman, 2005). Other research confirms the notion that professional development can be a beneficial outcome of research collaborations (Beaver, 2001; Wray, 2002). Perry et al. (2012) found their participants (faculty, postdocs, graduate students) were interested in receiving professional development. Participants were looking for mentors who could give them career guidance, incorporate them into professional networks, and socialize them to the academy. In addition, Perry et al. found participants were also interested in skill-building and hoped working collaboratively could facilitate content knowledge acquisition, teach them new techniques, and help them gain expertise in research methods.

Communication and information technology. Togetherness is important for members of research collaborations (Boschma, 2005; Pavangadkar, 2012; Rhoten, 2003), but physical togetherness can be limited by location, therefore communication is important to the effectiveness of a research group. When people are geographically dispersed, communication

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technologies (e.g., email, video conferencing) are critical both to keeping team members feeling connected and to the group's functioning (Boschma, 2005). Collaborators rely heavily on communication technologies, not only for the practical purpose of relaying information but also to help group members connect and develop relationships (Bracken, 2005; Brown, Poole, & Rodgers, 2002).   Technology is critical in helping to sustain relationships but some foundation must first exist. Although technology can help propel a functioning group, it cannot save a floundering one in which the interpersonal connection is tenuous: "collaboration requires intensive interaction that creates dependencies parties could exploit if they so desired. Trust is the glue that binds collaborators by fostering faith that both parties will contribute and not behave opportunistically" (Brown, Poole, & Rodgers, 2002, p. 117). As such, determining ways groups can most effectively be in contact with each other and having those technologies both readily available and working optimally is essential. To maximize technology's potential, however, collaborators must first determine how to build relationships within the group.

Summary

In this chapter I discussed the benefits of collaboration as they relate to stakeholders from researchers themselves to society in general. I then offered a detailed description of the MFIRC including external attention, intrinsic motivation, and systemic implementation factors. Perry et al. (2012) suggested a number of elements comprise the systemic implementation portion of the model: at a broad level, social and organizational factors and within those two factors, five sub-factors. Each of the five sub-factors, organizational values and identity; assessing and supporting faculty work, professional networking opportunities, professional development opportunities, and communication and information technology, was described in detail and contextualized within the literature. The following chapter discusses the methods chosen for the current study

and provides details about participant recruitment and protection, interview protocol

development, and plans for data analysis.

CHAPTER THREE: METHODOLOGY

The purpose of this study was to examine the systemic implementation portion of the MFIRC (Perry et al., 2012) to understand how well it described STEM/social science research collaborations. Before describing the research paradigm and case study design, participant selection, measures to protect participants, and data collection and analysis, I first discuss some of the methodology literature that influenced my approach to this research.

Several sources informed the execution of this study. Merriam (2009) and Yin (2009) both provided general guidance around conducting qualitative research. Stake (2005) and Miles and Huberman (1994) provided direction about conducting a multiple case study and data analysis. I make reference to additional authors in this chapter when their work provided further insight or addressed concepts not covered by Merriam, Yin, Stake, or Miles and Huberman. Using multiple perspectives to inform this study's design enabled me to provide a stronger and more specific research plan than would have been possible had I relied only on one or two authors.

Study

This study employed a qualitative methodological approach to examine how research collaborations are influenced by various factors. Qualitative research is appropriate when examining the type of research question that forms the basis for the current study - questions that aim to understand the how or why of an issue (Miles and Huberman, 1994; Creswell, 2009). Qualitative inquiry accommodates change and recognizes it is ongoing (Patton, 1990), which was important for this study because research groups are inherently dynamic given the numerous personalities and influential factors at work. A further benefit of qualitative inquiry is its ability to help investigators gain holistic or systemic overviews (Miles & Huberman, 1994) and to aid in understanding complex relationships (Stake, 2006). Collaborative groups do not operate in a

vacuum: context influences researchers engaged in collaborations. The systemic implementation portion of the MFIRC provides a major contextual component of the environment within which researchers work. External attention and intrinsic motivation, both of which are part of the MFIRC, provide two additional pieces of the contextual puzzle influencing collaborative researchers. As such, approaching this research with a method that accounts for context was important.

Simons (2009) praised the utility of case study for examining something complex and unique in a "real life context" (p. 21). Yin advocated using case study "because you wanted to understand a real-life phenomenon in depth, but such understanding encompassed important contextual conditions – because they were highly pertinent to your phenomenon of study" (p. 18). Case study is also appropriate when one's research question focuses on describing the how or a why of a situation, which is true of the current study and is helpful when studying contemporary rather than historical events over which the researcher has little or no influence (Yin, 2009). The current study examined the activities, group dynamics, and context of research collaborations as they happened. Although some questions focused on participants' recollections of events, the thrust of the project was to describe current phenomena. Additionally, I had no influence over the context or behavior of participants nor was this study intended to be an intervention.

Multiple case-study design. Knowing I wanted to understand what was happening with each group individually and also to compare and contrast across groups, led me to choose a multiple case-study design. Each group studied for this project was its own case. Stake (2006) described a case as an entity composed of people, processes, policies, challenges, and successes. Each collaborative group studied in the current research had its own "inside and an outside,"

which Stake (2006, p. 3) referred to as a *bounded system*. Stake acknowledged that although each case has its own story, when viewed together, one could gain an understanding of "the phenomenon exhibited in those cases" (p. vi). For the current study, the main phenomenon of interest was the experience of the research group and its similarity or difference to that which is described in the MFIRC.

A helpful way for me to visualize this project, and which ultimately led to my decision to conduct a multiple case study, was to imagine the MFIRC (Figure 2) with a large, rectangular frame around it. Within that frame lay the context, the actors, and the elements of the MFIRC comprising each case. I then imagined each case next to each other within a larger frame that represented the boundaries of the present study. In that larger outer frame lay the institutional context and the current state and federal climate. Stake (2006) warned that researchers might have difficulty "marking where the case ends and where its environment begins" (p. 3) but suggested one think of boundedness, among other things, to assist in being specific about the case.

Unit of analysis. This study had three cases and therefore three main units of analysis. Although an *embedded case study* also takes into account sub-units of analysis (Stake, 2006; Yin, 2009) the current research focused on each group as a case rather than various permutations and combinations of relationships within each specific case. Further, data from each case were examined separately but then pooled and re-examined in the aggregate (Stake, 2006). As such, this research project is a *holistic case study* (Yin, 2009).

Case Study Site

Bridgetown State University (BSU) is a large, public, land grant institution located in the Midwest. According to Carnegie Classifications, BSU is a very high research activity institution and enrolls about 49,000 students. The study's cases were all selected from BSU for two reasons:

(1) being a research intensive university afforded a large and academically diverse pool of potential participants; and (2) choosing cases from the same institution facilitated multiple-case analysis by ensuring a number of contextual factors were the same or similar for each case.

Participant Selection

Merriam (2009) suggested qualitative research usually uses sampling techniques that are not random, are purposeful, and are small. This study used *criterion sampling* to select participants (Miles & Huberman, 1994). Criterion sampling ensures each case meets specific criteria and Miles and Huberman suggested the method is helpful for quality assurance. The criteria I used for selection were (1) participants were engaged in an interdisciplinary research group based at BSU, (2) participants were faculty, postdocs, or graduate students, and (3) the collaboration involved people from STEM and social sciences backgrounds only. The purpose for each of the criteria is as follows: First, I wanted to interview people based at BSU to keep the institutional context (i.e., some elements of external attention and some systemic implementation factors) consistent, which would help me to see the role the institution played with each group. I wanted participants to be faculty, postdocs, or graduate students because although other people can be important to the work of research team (e.g., lab technician, departmental administrative support staff), only faculty, postdocs, and graduate students are influenced by the MFIR sub-factor called assessing and supporting faculty work. Similarly, I excluded groups who were partnered with private industry given the systemic implementation portion of the model focuses on the academic environment and does not account for market, or other influences, in the private sector. I included only graduate students because they are evaluated in ways that align with how faculty are evaluated (e.g., conduct independent research, generate publication worthy papers) therefore the model element assessing and supporting faculty work is also applicable to them. Although undergraduates can be valuable members of interdisciplinary teams, the focus on

undergraduate research tends to be more about benefits for the student in terms of their own learning and development (Hunter, Laursen, & Seymour, 2007; Healey & Jenkins, 2009), not about their contribution to advancing the mission of the interdisciplinary team. For this initial study of the utility of the MFIRC, I wanted to focus narrowly and only on people for whom the model elements are known to fit well. Finally, I interviewed people from groups composed only of STEM and social science people because much has been published on the collaborative work of STEM groups but social science and STEM researchers are increasingly working together and that trend will continue in the future (Bastow, Dunleavy, & Tinkler, 2014). Exploring how groups function when their members come from significantly different research paradigms is important to improve understanding of how best to support the success of STEM/social science collaborations.

I approached participant selection in three ways. First, I conducted searches of the BSU website to determine if faculty in particular areas (i.e., STEM and social sciences) were involved with collaborative work. Second, I combed an author database, created by BSU to support interdisciplinary researchers, which lists faculty publications and includes a network analysis of their collaborators. Finally, I spoke with knowledgeable people at BSU who recommended researchers to contact. To determine people to invite, I reviewed their collaborative publications and read about their coauthors to determine if the team met my study's inclusion criteria. Once I created a list of potential participants, I compared and contrasted them in order to ensure there were no overlapping people between groups, which helped achieve maximum variation among my participants (Merriam, 2009). Maximum variation sampling involves choosing participants from "widely varying instances" to help find "those who represent the widest possible range of characteristics of interest for the study" (Merriam, 2009, p. 79). Although some elements of

convenience sampling (e.g., I could only interview people who actually responded to my requests) were used in this study, research relying solely on convenience sampling strategies "is likely to produce information-poor" findings (Merriam, 2009, p. 79).

I sent emails to potential participants outlining the nature and purpose of the study (Appendix B), the Institutional Review Board (IRB) approval information, and invited them to complete a brief eligibility survey (Appendix C). In the eligibility survey I asked if they had or were currently collaborating with people at BSU, what field of study both they and their collaborator(s) were in, and if they were interested in participating in this study. Those who indicated interest in participating were prompted to share their list of collaborators so I could contact them also.

Using an eligibility survey helped identify participants who met the criteria of being engaged in collaborations with others at BSU but who may not yet have published their findings. The survey also helped me to determine whether my initial assessment of people's STEM or social science affiliation was correct; I encountered numerous people who worked in STEM departments but who were, in fact, social scientists. Additionally, the eligibility survey alerted me to participants I had not managed to find myself, which introduced a third type of sampling into this study: snowball sampling (Merriam, 2009). Snowball sampling involves being referred by participants to other potential participants and, as the name suggests, can help one's participant base grow (Merriam, 2009). As illustrated in Table 1, my recruitment efforts yielded three groups each with five people (n=15). The column entitled *Participation* denotes which rounds people agreed to be interviewed for.

Table 1

Study Participants

Case	Name	Position	Field	Participation
One	Anya Fraise	PhD Student	STEM/Soc. Sci.	Both Rounds
One	David Webb	Assistant Professor	STEM	Round 1
One	Jenny Miller	PhD Student	STEM	Both Rounds
One	John Degen	PhD Student	STEM	Both Rounds
One	Susilo Gunadi	Associate Professor	Social Science	Both Rounds
Two	Laurie Stroud	PhD Student	Social Science	Both Rounds
Two	Lonnie Elamb	Master's Student	STEM	Round 1
Two	Mike Myers	PhD Student	Social Science	Both Rounds
Two	Sam Loomis	Associate Professor	Social Science	Round 1
Two	Terrence Wynn	Professor	STEM	Both Rounds
Three	Donny Kerabatsos	Postdoc	STEM	Both Rounds
Three	Jeffrey Züppe	Assistant Professor	STEM	Both Rounds
Three	Maude Lebowski	Associate Professor	Social Science	Both Rounds
Three	Phillip Brandt	Professor	Social Science	Both Rounds
Three	Walter Sobchak	Professor	STEM	Both Rounds

Methods to Protect Participants and Institutional Review Board Protocol

Much research is dependent upon the participation of human subjects so ensuring they are treated ethically and that their privacy is protected is a primary responsibility for investigators. This section describes how I met the BSU Institutional Review Board (IRB) requirements for the ethical treatment of research participants. Unlike some data collection techniques, interviewing participants means they cannot remain anonymous. To protect their privacy, I assigned pseudonyms that would represent them throughout the transcription, analysis, and reporting of the data. Additional identifying information (e.g., funder names, campus-specific locations) was changed in the transcripts for example, when participants mentioned the institution Bridgetown State was substituted. Similarly, colleagues or other identifying locations were given pseudonyms.

This study made no use of deception and the purpose and rationale of the research were clearly explained to participants when inviting them to be part of the project, verbally upon meeting, and again on the informed consent document. In terms of other forms of harm, participants faced minimal risk other than the time consumed by arranging and engaging in the interview and possibly feeling some discomfort when discussing issues that arise in their day-to-day work in their research collaboration. No financial conflicts of interest influenced this study. Participants received no incentive to participate nor was this study funded aside from two small grants awarded by the College of Education at the researcher's institution. Participants and the researcher had no prior relationships that would be considered interpersonal conflicts of interest (e.g., supervisor/supervisee).

Further details of protections regarding audio-recorded data are provided later in the following section entitled D*ata Collection* where I discuss interview protocol and data storage. All data were uploaded both to my password protected computer and password protected cloud storage account. I did not print transcripts therefore consent forms were the only identifying paperwork associated with this project and they were stored in a file at the researcher's home. All other data including transcripts and analysis were transferred to online, password protected qualitative analysis software called *Dedoose.* By the time I uploaded the data to Dedoose, all data had been de-identified.

Data Collection

A number of authors suggest qualitative research involves multiple forms of data including documents, field notes, interviews, and other sources (Creswell, 2009; Miles & Huberman, 1994; Stake, 2006; Yin, 2009). Data for this study came from two rounds of interviews with participants and this section describes the methods for doing so.

Interviews

Interview protocol development. I developed interview questions for round one based on the MFIRC and extant literature. To begin, I drafted questions to elicit information about participants' research group, their group's purpose, and how they were funded. I then created questions focused on the systemic implementation portion of the MFIRC.

Pilot testing. To determine the efficacy of my protocol, I pilot-tested questions by interviewing seven people who had worked on an interdisciplinary STEM/social science team but whom had not been identified as potential participants for my main study. I conducted in-person, audio-recorded pilot interviews until I was able to modify the protocol to capture what I wanted to learn, participants did not have to ask clarifying questions, and I began hearing similar answers to my questions. I then began data collection with participants eligible to participate in the study.

Protocol development for round two. Analysis of round one interviews informed the design of the protocol for round two. By the end of round one, I had sufficient information about how the MFIRC fit to each group so I created three questions for round two that would elicit information about the broader areas that emerged as themes in the data: how people find collaborators, integration of the group's work, and whether people thought training for interdisciplinarity would be useful.

The purpose for the question about finding collaborators was to understand how people put together their research groups and what they intend to do in the future to find collaborators for new projects. Integration of ideas is discussed in the literature as a desired outcome of interdisciplinary groups but the concept was not included as part of the MFIRC. The original Rhoten (2004) model and the Perry et al. (2012) iteration almost presume that if the group can be supported to do its work, integration will happen. I wanted to understand more about how groups

perceived integration and whether they considered the work of their team to integrative. Finally, I wanted to understand how people perceived training as a means to prepare teams for interdisciplinary work.

Conducting interviews. I conducted two rounds of interviews with participants during this study and followed the same procedure for both rounds. I arranged to interview participants in-person and in a private environment. When meeting in-person was not possible, I conducted interviews via Skype or telephone. After reiterating the purpose of the study, reviewing the IRB information with participants, and obtaining their written consent for both participation and audio recording, the interview began. During the first round, interviews with participants were scheduled for an hour. During the second round, I booked a half hour with each participant. I followed the interview protocol I developed and asked clarifying and probing questions when necessary. After the interview was complete, I thanked the participant, switched off the recorder, and reiterated my contact information so participants could connect with me if they had questions. Immediately following the meeting, I uploaded the audio file to my password protected computer and to a password protected cloud storage website. I then deleted the audio file from the digital recorder so no unauthorized person could access the raw data.

Analysis plan. This section describes both the thinking behind the analysis and the actual tasks related to processing and reviewing the data. I begin with information about the phases of data collection and analysis and discuss my analytic strategy. Finally I share how I conducted the cross-case analysis.

I conducted data collection and analysis for this study in four phases. In phase one, I interviewed my participants, transcribed, uploaded, coded, and analyzed data by individual and by research group. During phase two, I looked across cases so I could understand how well I was

addressing the research question from a holistic perspective rather than just on a case by case perspective. When I determined how well the data aligned with the MFIRC, I drafted the protocol for round two interviews. During phase three, I interviewed participants a second time then transcribed, uploaded, coded, and analyzed the data by individual and by case. During phase four, I looked across both interviews from participants and coded round one interviews with any new codes that emerged in round two and coded round two data using codes developed in round one. Doing so gave me a comprehensive view of how all codes applied to all data regardless of when it had been collected. Re-coding the data a final time also allowed me to update my initial MFIRC visualizations (discussed later in this section) for each case to illustrate if and how round two data influenced the fit of the model. When I had comprehensively coded all the data from both rounds and had updated my visualizations, I conducted the complete cross-case analysis.

Analytic strategy. Following each interview, I transcribed the audio-recorded conversation and at that time, de-identified the data by substituting pseudonyms and alternate descriptors of specific locations. I sent transcripts to participants for review and, where applicable, made changes they requested (e.g., further mask the data). After transferring transcripts to Dedoose, I coded them based on Miles and Huberman's (1994) coding categories: *descriptive*, *interpretive*, and *pattern*. Descriptive codes are described as ones requiring little interpretation (Miles and Huberman, 1994). In the case of the current study, descriptive codes are the ones I attached to items I asked about specifically (e.g., how people were funded, model sub-factors). Coding was an iterative process; data I did not assign descriptive codes to initially went un-coded. Once two to three interviews were coded, I began to understand more about emerging themes and subsequently developed interpretive and pattern codes. Miles and Huberman suggest interpretive codes are ones where the researcher thinks something deeper is happening than what

can be seen through descriptive codes. I created a number of interpretive codes as I went through the transcripts and would then review previously coded work to look for sections that could be captured under the new code. Finally, I created pattern codes. Miles and Huberman describe pattern codes as ones involving both more inference and explanation than either interpretive or descriptive codes. The authors suggest that pattern codes are often used later in analysis, after descriptive and interpretive coding has been done, to represent a pattern the researcher identified. I developed a few pattern codes during this study and the best examples are the codes for the three main elements I focused on during my round two interviews: *training*, *integration*, and *network construction*. Similar to my procedure with interpretive coding, I re-read all transcripts to find data that would fit with the new pattern code.

Engaging in iterative analysis was helpful because I was able to code and re-code data to capture it as accurately as possible. Further, I was able to see where I needed to tweak an interview question to make it clearer, for example, or to garner information that others had provided, that was germane to the study, but about which I had not asked specifically. Miles and Huberman (1994) recommended ongoing data analysis rather than waiting to code and review after data collection ends. They warned leaving analysis until "the end" could create the problem of analytic overwhelm for the researcher who is then faced with a mountain of raw data. Ongoing analysis also helps the investigator to recognize developing patterns. Miles and Huberman suggested one could alter interview protocol and incorporate a question about something emergent from previous interviews; this flexibility is one of the hallmarks of qualitative research (Merriam, 2009; Miles & Huberman, 1994; Patton, 1990) and another reason why a qualitative approach was best for this study.

I approached the analysis on three separate levels: individual interviews, cases, and the multiple case analysis. Once each interview was coded, I then studied my work to determine how codes were (or were not) developing into themes (i.e., through pattern coding) and then, how the data aligned with the MFIRC. To visualize how data mapped to the MFIRC, I plotted the codes corresponding to each participant's interview onto the MFIRC. Doing so allowed me to see how someone's data clustered on existing factors and also what new elements had emerged.

I applied the same strategy used with individual interviews to my initial case analysis. I looked at themes to determine how the data aligned, or did not, with the MFIRC. I did so by reading transcript elements broken down by individual codes and also by plotting the entire group's data onto the MFIRC, which provided a helpful visualization. Once I had an idea of how my findings for each case were relating to the MFIRC, I looked at findings that seemed to fall outside of the theoretical framework. I turned back to the literature to understand how others had written about these phenomena before, which helped me make sense of themes that emerged. I then set about writing a report for each case that included descriptions of the research group, its field of study and the collaborative's objective and then discussed my findings and provided my interpretations (Merriam, 2009; Stake, 2006).

I was careful to focus attention on individual cases before turning my attention to the cross-case analysis. Stake (2006) suggested the individual cases should not be combined too soon and Yin (2009) warned researchers against melding the cases and jumping to cross-case analysis before thoroughly analyzing each case on its own. Once I had a report for each case, I was able to return to my research notes and the case reports to begin the cross-case analysis.

Cross-case analysis. Stake (2006) provided guidance for cross case analysis when he said, "the main activity of cross-case analysis is reading the case reports and applying their findings of situated experience to the research questions" (p 47). Rather than list findings as they relate to each aspect of a research question, Stake suggested each case's findings should "keep their contextual meaning" while writing the cross-case report (p. 47). Unlike the individual case reports, the cross-case report did not require repeated description of setting and participants or a factor-by-factor reiteration of how data fit to the MFIRC. For the cross-case analysis, I instead looked at the major emergent themes from the study and created a report highlighting those elements.

Assessing the Quality of Qualitative Research

Readers of research want to know they can trust findings and recommendations, so discussing steps taken to ensure research is valid and reliable or authentic and trustworthy is incumbent upon researchers. Not all authors agree on how to describe the quality of qualitative research. For example, Yin (2009) and Miles and Huberman (1994) discuss quality assurance methods in very different ways. In fact, there is much disagreement, not only in terms of how to judge but also what to judge – Yin uses terms like validity and reliability and others use terms like trustworthiness and authenticity (Merriam, 2009). Although this study is somewhat informed by the work of Yin, his criteria for judging the quality of qualitative research designs are not the template I used for this project; c*onstruct validity* or *internal validity* are terms often associated with quantitative research and Yin's instructions to investigators to "test" (p. 41) for those elements did not fit with my own understanding or others' interpretations (Miles & Huberman, 1994; Stake, 2006) of addressing quality. Although Merriam uses terms like reliability and validity in her writing, she does so because most people learn about qualitative research after learning about quantitative methods and as such, are already familiar with its terminology. She

therefore discusses "trustworthiness and rigor in qualitative research with reference to the

traditional terminology of validity and reliability" (p. 209). Trustworthiness is a product of

researchers' ability to illustrate rigor in how they conducted their study (Merriam, 2009).

Helping readers follow the study from inception to conclusions and demonstrating how a

conclusion "makes sense" (Firestone, 1987, p. 19 in Merriam, 2009, p. 210) is incumbent upon

researchers and helps create trustworthiness.

Merriam's (2009) explanations of credibility (internal validity), consistency (reliability),

and transferability (external validity), along with Miles and Huberman's (1994) advice to

investigators about protocol design, data collection, and data analysis became my resources

regarding the production of high quality research. The following sections expand on credibility,

consistency, and transferability and demonstrate the rigor of the current study.

Credibility. This study attempted triangulation as a strategy to build credibility.

Triangulation involves using multiple methods, multiple sources of data, multiple types of data,

and/or multiple researchers (Miles & Huberman, 1994; Merriam, 2009). Using multiple

investigators was not possible given this project was a dissertation and the expectation is

independent inquiry. I was able to use multiple sources of data (people, social media/blogs,

publications) and also multiple types of data (first-person accounts and document analysis). A

final strategy I employed to aid in triangulation and bolster credibility was to send transcripts to

participants for review.

Credibility in qualitative research has been likened to internal validity in quantitative

research and is concerned with how aligned findings are with reality (Merriam, 2009). There are

a host of problems with trying to measure reality not least of which is that reality is different for

everyone. As such, credibility in qualitative research aims to come as close as possible to

representing participants' truths or realities while recognizing no perfect interpretation exists. One method of adding credibility is through triangulation. Another way to build credibility within a study is to use a peer debriefer with whom the researcher can share findings and check assumptions. During this study, I met regularly with a peer debriefer to discuss my thought process around data analysis and findings. I also involved several other colleagues near the end of my study to elicit feedback on iterations of the model I developed.

Consistency. Consistency has been compared to reliability in quantitative research and reliability is concerned with the replicability of findings. In qualitative research, consistency is about whether or not the findings are congruent with the data one has collected (Merriam, 2009). Triangulation is also helpful in supporting a study's consistency. Yin (2009) and Lincoln and Guba (1985) both refer to audit trails and Merriam (2009) included audit trails as a strategy for boosting consistency. Artifacts in the current study's audit trail include descriptions of the extant literature and the derivation of the MFIRC, descriptions of the methods used to recruit and protect participants, and researcher notes. The goal of consistency-related strategies is to illustrate how one arrived at one's conclusions (Merriam, 2009).

Transferability. Qualitative researchers are not usually concerned with their findings being transferable to different scenarios. Unlike some quantitative research which can be generalized to larger populations, qualitative research tends to focus on in-depth understandings of events or phenomena within specific conditions. Qualitative studies are usually conducted because a researcher wants to "understand the particular in depth, not to find out what is generally true of the many" (Merriam, 2009, p. 224). Merriam argued, however, that sometimes the general lies in the particular and sometimes an experience arises, like a participant's description of something that is so poignant it could be considered almost universal. So, although

I was not interested in generalizing or transferring my findings to all researchers everywhere, my contribution was to provide as much information about my cases as possible so that others could decide for themselves whether or not my study applies to them (Merriam, 2009). One way to go about providing ample information is to use maximum variation in the sample (Merriam, 2009). As reported earlier, I selected research groups as different from each other as possible in order to maximize the variation in my participants. An additional way of enhancing transferability is to offer rich description. Merriam suggested rich or thick description entails offering detailed descriptions of the setting, participants, and the findings along with ample quotes from notes, documents, and participants.

Summary

For this multiple case study, I conducted two rounds of interviews with 15 participants: one postdoctoral fellow, six graduate students, and eight faculty members. After each round of interviews, I reviewed data by individual, by case, and also across cases to understand how I was progressing toward addressing my initial research question: How well does the MFIRC fit to described the experiences of STEM/social science research groups. In the following chapter I provide more detailed descriptions of BSU and my participants and deliver my findings in three separate case reports.

CHAPTER FOUR: CASE STUDY REPORTS

In this chapter I report findings from each case as well as present a multi-case analysis. Prior to case analyses, I revisit the research question guiding the study. Next, I describe the study location, Bridgetown State University (BSU), to place the research within its institutional context. I then review the main characteristics of the Model of Factors Influencing Research Collaborations (MFIRC). Finally, I report the findings from each case study and from the cross case analysis.

The findings from the cases are presented as follows: First, I describe the people involved and their roles on their research team. I then describe how their data mapped to the MFIRC and discuss additional factors that emerged during analysis. Next, I discuss findings from round two of my interviews with participants and summarize how well the MFIRC describes the experience of the group. Cases One, Two, and Three are discussed in order and their names reflect the order in which they entered my study as participants. To protect the privacy of participants, each person and the institution have been given pseudonyms and all identifying information including field of study, the group's research focus, important dates, and the group's funding agency have been redacted. Following individual case analyses, I present the multi-case analysis, which discusses the data from all cases in relation to the MFIRC and lays the foundation for Chapter Six where I incorporate my findings with the literature and discuss the implications and limitations of this study.

Purpose and Focus of the Research

The question driving this study was how well does the MFIRC describe systemic implementation factors influencing investigators at a large, research university who are engaged in combined STEM/social sciences research collaborations? The model at the center of the study, the MFIRC (Figure 2), is composed of three main factors; external attention, intrinsic motivation,

and systemic implementation. Under systemic implementation, there are five sub-factors: assessing and supporting faculty work, communication and information technology, organizational values and identity, professional development opportunities, and professional networking opportunities.

Institutional Context

Bridgetown State University is a large, public institution located in the Midwestern United States and is considered a research university, very high research activity (RU/VH) according to Carnegie Classification system (Carnegie Foundation for the Advancement of Teaching, 2014). In 2012-2013, BSU had about $475 million in external research funding half of which came from federal sources. The two agencies awarding most of BSU's federal funds were NSF and NIH (Redacted, 2014). The university takes 53.5% of externally funded research awards. Some of that money does flow back to colleges and departments via indirect cost credits (IDC) based on a formula that accounts for faculty appointment type and research space, among other things. Participants in my study discussed IDC or "indirects" frequently because for every dollar they need for research, they must apply to the funder for twice the amount.

Bridgetown State has several interdisciplinary research centers and several interdisciplinary programs on campus. Interdisciplinary research has become a focus at BSU and has significant resources devoted to it. I wondered about the culture of interdisciplinary research at BSU and asked about how faculty receive messages about interdisciplinary collaboration. Across all cases, faculty said BSU is particularly focused on interdisciplinary projects and Dr. Maude Lebowski, a PI from Case Three, nicely captured the general sentiment I heard from my participants:

> She's [Dean of Dr. Lebowski's college] been articulating that message [engage in interdisciplinary research] enough now that chairs are articulating it to us. So it just seems to be coming from everywhere above – the Provost, multiple deans, chairs – that

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this is what the institution is really investing in. They've created new positions and created new offices to try and facilitate exactly this so they have been very on target with their message. They've been very consistent in their message so I feel like I've gotten it from multiple sources.

Dr. Lebowski later went on to say, about how BSU presents its interdisciplinary push to faculty, "some of them [other research universities] may have more finesse than BSU so they may be saying they want to address the really big problems. BSU is really crass about it [and says] 'we want to bring in the big dollars.'" However tastefully it has or has not been presented, BSU's message about the importance of interdisciplinary research is clear.

Declining state appropriations also influence BSU's push for research dollars. State funding accounts for about 22% of BSU's budget and since 2002-03, appropriations have shrunk by 20%; that has put pressure on the institution to seek funding elsewhere and, in turn, academics are increasingly expected to bring in external research dollars.

MFIRC Components

The Model of Factors Influencing Research Collaborations, illustrated in Figure 2, is composed of several main- and sub-factors. At the top of the triangle is external attention, at the bottom of the triangle is intrinsic motivation. Systemic implementation is in the middle of the triangle and is composed of five sub-factors: assessing and supporting faculty work, communication and information technology, organizational values and identity, professional development opportunities, and professional networking opportunities. Each of the aforementioned factors have been shown within the literature, and also by Perry et al. (2013), to influence interdisciplinary research teams.

The issue of intrinsic motivation. As I analyzed each of the interviews, then the cases, and finally conducted the cross-case analysis, intrinsic motivation did not emerge as a factor wielding influence over groups. *Intrinsic* motivation is defined as "the doing of an activity for its

inherent satisfactions rather than for some separable consequence" (Ryan & Deci, 2000, p. 56).

Alternatively, one would call someone extrinsically motivated "whenever an activity is done in

order to attain some separable outcome" (Ryan & Deci, 2000, p. 60). During analysis, the

concept of motivation emerged but not intrinsic motivation exclusively and not in the neat, tidy

way illustrated in the MFIRC.

A further problem with intrinsic motivation as it appears in the MFIRC is with its

placement in the model. A fuller discussion of the appropriateness of the shape of the MFIRC

appears in Chapter Six but in terms of how intrinsic motivation is represented, because it forms

the base of the triangle, it can appear to be the most important element of the model. Issues with

the shape and placement of intrinsic motivation were raised by two peer debriefer one who

assumed intrinsic motivation was the foundational element of the model and the other who

assumed that, like many triangular or pyramid-shaped models, there is a progression from

bottom to top. Neither hierarchy nor importance should be implied in the MFIRC. Given the

problems with the narrowness of intrinsic motivation's definition and its placement in the model,

I chose not to report findings on intrinsic motivation and instead incorporated the theme of

general motivation into the sub-factor organizational values and identity. During interviews,

people referred to motivation in ways similar to how they spoke about interpersonal issues (e.g.,

getting along with others, openness to ideas) so adding motivation to the organizational values

and identity category was an appropriate fit. In Chapter Six, I revisit the topic of motivation as I

discuss the future of the MFIRC.

Case Study One

The research group from Case One was composed of five faculty members and three

graduate students (Table 2). All of the graduate students and two of the faculty, Dr. Susilo

Gunadi and Dr. David Webb, agreed to participate in this study. Fortunately, the two faculty

members most closely involved with the research team were also the ones who were interviewed for this study. The three other faculty members on the team did not participate: Dr. Steven Krantz was away on sabbatical and declined to be interviewed and multiple attempts to contact Drs. Davis and Smith went unanswered.

Table 2			
Case One Research Group Members			
Participation	Name	Position	Field
Both Rounds	Anya Fraise	PhD Student	STEM/Soc. Sci.
Round 1	David Webb	Assistant Professor	STEM
Both Rounds	Susilo Gunadi	Associate Professor	Social Science
Both Rounds	Jenny Miller	PhD Student	STEM
Both Rounds	John Degen	PhD Student	STEM
Non-Participants	Adam Smith	Associate Professor	Social Science
	Morgan Davis	Associate Professor, FT*	Social Science
	Steven Krantz	Professor	Social Science
Note: *denotes Fixed-Term faculty appointment			

Background of the Research Group

The research group in Case One began to take shape before Dr. Gunadi had even arrived at Bridgetown State. During the time between accepting his position at BSU and arriving on campus, a colleague in the college where he was to work forwarded him an email about helping with an international study abroad opportunity. Dr. Gunadi connected with Dr. David Webb who was running a study abroad to what later became their study location. During the spring of Dr. Gunadi's first year at BSU, he and Dr. Webb co-led the study abroad where they spent time discussing the area and began to formulate possible research questions. Soon after they determined a suitable program through National Funding Agency (NFA) to which they could apply. The first time they submitted, they received "a pretty flat rejection" according to Dr.

Webb. The NFA reviewers determined their research questions were too large for the group they had assembled.

For their second attempt at the grant, which was successfully funded, they enlisted Drs. Smith, Davis, and Krantz to participate and did so after Drs. Gunadi and Webb had developed most of the project. Drs. Smith, Davis, and Krantz are all social scientists who could provide specialized skills to the study. Dr. Smith is experienced in relevant research methods, has worked in the study region, and speaks the language of the study community. Dr. Davis also has familiarity with the region and specialized research methods. Dr. Krantz's lab provides key data analyses to the project. Dr. Krantz, although listed as a co-PI on the grant, was recruited for a specific data technique. Dr. Gunadi explained it as follows, "we always knew that he would be – he was almost, kind of, the wise soul. He just knew how these things [interdisciplinary research projects] worked. He was more a consultant than he was an active participant and he knew that and we knew that so there wasn't any kind of difference in expectations." Jenny Miller and John Degen, both PhD students, were accepted to BSU to work with Drs. Gunadi and Webb and have been on this project since it was funded. Anya Fraise was accepted to BSU a year later and joined the team in the project's second year.

The group was funded by NFA for five years for around $1 million and they received a no-cost extension to complete their final data collection. Drs. Davis and Smith were incorporated into the grant as equal partners to Drs. Gunadi and Webb, but over time, that work arrangement has shifted dramatically. Initially the group (i.e., the four core PIs: Gunadi, Webb, Davis, and Smith, and the two PhD students, Jenny and John) traveled to the study location and worked closely together both there and when they returned to the United States. Eventually, however, Dr. Davis took on an administrative role in her department and became less involved with and

responsive to the group. Dr. Smith, unfortunately, suffered a major health event and his work at BSU, and subsequently with this research group, was curtailed significantly. Around the time Drs. Davis and Smith began to retreat from the project, Anya Fraise, another PhD student working with Drs. Webb and Gunadi, was brought onto the team.

Because of a funding agency regulation that allows only one person to be the principal investigator (PI), Dr. Gunadi is technically the PI on the project and all other faculty are co-PIs. Drs. Gunadi, Webb, Davis, and Smith shared responsibilities for project development through the first phases of the research although it was actually Gunadi and Webb, along with their three graduate students, who have maintained the project's momentum since Davis and Webb became less involved. Similarly, Dr. Gunadi is officially the advisor for all three graduate students because, at the time of their acceptance to BSU, Dr. Webb had a fixed-term appointment and institutional regulations required advisors to be tenure stream faculty.

The following sections describe how well various components of the MFIRC fit to describe this research team. A number of elements not included in the model emerged during interviews and I discuss those as well.

External Attention

Funding and funder policy were the salient external forces influencing this research group and participants mentioned the role of funding/funder policy numerous times. External attention played a role with this team in that their research questions were tailored specifically to a request for proposals (RFP) by NFA rather than just to the expertise and interests of group members. The group's future research will also be framed with funding in mind: "I think its impossible to find a funder that would just give us money to do basically the same stuff we have been doing but just for a longer period of time. Science doesn't work like that. But I think we can find creative ways to repackage it in some ways." (Dr. Webb).

Systemic Implementation Factors

This portion of the case report focuses in detail on the five sub-factors that comprise systemic implementation: assessing and supporting faculty work, communication and information technology, organizational values and identity, professional development opportunities, and professional networking opportunities.

Although there are five sub-factors in the MFIRC, Rhoten (2004) initially created her model without discrete categories under systemic implementation. As originally described by Rhoten, systemic implementation includes university structures and functions and I did code transcripts for "generic" type systemic implementation factors that did not fall under specific sub-categories. In the case of this research team, the structure of BSU facilitated their ability to reach across campus to find potential collaborators like Morgan Davis, "things like the research centers and international studies and programs and [center name] - the organization of those structures, I think. So the centers structure that BSU has helped" (Dr. Webb).

Communication and information technology. Participants from this research group all reported their team's communication is effective. Group members are in touch formally during meetings they schedule for the entire team two to three times per year and through meetings with the two main PIs, Drs. Gunadi and Webb, and the graduate students. Meetings with Webb, Gunadi and the graduate students are far more frequent and serve the purpose of advancing the overall project but also help the graduate students move forward with their own dissertation work. Meetings with one PI and a graduate student are also common and all three of the students reported feeling comfortable approaching Drs. Webb and Gunadi and all felt confident if they had something to discuss with one or both of the PIs, the professors would make time for the students.

The team uses time together about twice per year to update everyone on the project's progress, "bounce ideas off each other" (Anya Fraise), and "brainstorm different ways to approach" individuals' research within the larger project (Dr. Gunadi). During informal meetings with the five most active members of the team, a lot of idea-sharing and discussion also takes place. Participants all reported their meetings were productive. The graduate students talk among themselves, share ideas, and help each other where possible. Similarly, Drs. Gunadi and Webb talk amongst themselves and both reported feeling confident their co-PI was invested in and committed to the project and was doing his best to advance the work of the team. Overall, the group communicates well, shares information and ideas freely, and members are supportive of each other.

Role of technology. Technology plays an important role in this group's communication. The team dispersed across campus and for most of the year, one or more of the group members is living in the country where the study takes place. As such, most of the group's communication is done through email, which is not only fast and convenient, but also ensures relevant parties are included on messages and has the added benefit of creating an archive of events and decisions. Getting the group together often involves using Doodle polls for scheduling and normally means conducting meetings via Skype. Despite the challenge of being separated by distance and time zones, having someone at the study location can be beneficial. Jenny, a doctoral student on the team, mentioned how convenient it is for whomever is living on site to procure data or information and get it to the rest of the team quickly. Inquiries from BSU to study partners overseas, that might normally take a protracted amount of time, can be handled in mere minutes when one of the team is on-site. Further, the person on location can continue to cultivate and maintain relationships with constituents in the study region.

Influence of disciplinary boundaries on communication. I asked the group how disciplinary boundaries influenced the team's communication. The broad research topic this team works in is, by nature, highly interdisciplinary and because the group formed around the topic, disciplinary silos have not been a problem for the group. Both main PIs are cross-appointed and Dr. Gunadi's doctoral program involved extensive interdisciplinary work. All three of the PhD students on the team were admitted to the department and program where Dr. Gunadi and Dr. Webb are partially appointed. The doctoral students sought this academic program at BSU specifically for the type of work being conducted by Webb and Gunadi and because the program is interdisciplinary. As such, working across disciplines did not pose major challenges for this group.

One area where disciplinary boundaries did become apparent was when the team was writing for publication. Jenny described the experience of having to learn about framing a publication for a particular audience and a particular discipline's journal. Rather than describe this as a problem, she merely said she "noticed it." Similarly, Dr. Gunadi remarked there had not been any divisions or problems caused by disciplinary boundaries: "so discipline, I don't think, has been a problem in terms of the cohesion of the group."

Organizational values and identity. I asked the group about their sense of affinity towards each other and how much of a sense they had that team members were "their people." Everyone I spoke with on the team said they felt affiliated with the group and, at least in terms of work, that these indeed were their people. Dr. Gunadi and Dr. Webb both mentioned the other and described their positive and productive working relationship with each other. They were both careful to describe Dr. Krantz as an advisor to the group – as someone to whom they could turn for guidance. Both were also clear that relations between themselves and Drs. Davis and Smith

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were somewhat strained given the lack of participation and lack of communication about their intentions to resume work with the project. "For Morgan Daniels and Adam Smith, because their involvement in the project has been really minimal, I don't feel like they are my people or that any bonds have been formed that would make me look to them for collaboration in future projects" (Dr. Gunadi).

Getting along. Some of the group's cohesion was attributed, by Dr. Gunadi, to the members themselves, "I think the people maybe have the personalities to sort of work together and get along." The five core members of the team also brought passion for their subject matter, care for the region in which the study is located, talent, and a hardy work ethic to the project. Drs. Gunadi and Webb both articulated how grateful they were to have such a strong complement of graduate students on the project. Between them, the students were awarded a mix of internal BSU funds and also nationally and/or internationally recognized scholarships. One of the main things Dr. Webb said he learned as a result of being part of this team is that "I didn't have to do all the work myself" and that he can rely on the graduate students for important components of the project. About John, Dr. Webb said, "we didn't have a great plan in place for how we were going to do [component of the research] when we started the project. We knew that we wanted to do it and he really helped design a very thorough experiment, a very thorough project." In turn, the graduate students reported feeling supported by Drs. Gunadi and Webb and that, for the most part, communication is open, frequent, and productive.

Anya Fraise did mention one issue that makes her "uncomfortable" about the group:

> One of our team members sort of has some disdain for [branch of social science]. Being that we're an interdisciplinary team and we have worked with [people from branch of social science], and of course they sort of keep that to themselves but I'm privy to some discussions that go on behind the scenes, that made me uncomfortable. I thought we're supposed to be this open-minded, interdisciplinary team but I sort of see your real thoughts on some of these things. I think as somebody who has a real appreciation for

[branches of social science involved with this team's research] despite the field I'm currently in [Anya is technically placed in a STEM discipline], you know, that's a little bit disappointing. But, other than that I don't think…I mean I think the team's very collaborative, they're open about sharing information, very willing to help each other out.

Anya did share that the person in question is a co-PI on the team but did not disclose to whom she was referring. As she stated at the end of the quote, she still finds the team to be supportive and productive. Further, this passage came from near the end of her second interview – almost as an after thought. At no time during our first discussion did she mention feeling a division between STEM or social sciences and, despite reporting this problem her commitment to the team or the work did not seem to be suffering.

Fairness. Participants from Case Study One mentioned the group's openness to ideas, willingness to share information, and to help each other. Early in the group's formation, Dr. Gunadi led the team in a meeting where they laid out guidelines about authorship (e.g., what constitutes inclusion on a paper, how author order should be addressed and decided upon). Because the graduate students in Case One need to write publishable articles as part of their exit requirement, I asked the graduate students about issues of authorship credit within the group. Anya came on board after Dr. Gunadi's initial discussion of authorship guidelines so she was unaware that had taken place. Also, because she came later than the other doctoral students, at the time I met with her, she had not yet written a paper for submission to a journal. Jenny said she had definitely been given credit for work she had done and felt her placement in the author order on publications had been fair. Jenny said her advisor Dr. Gunadi, "is pretty levelheaded and he's very easy to approach about those kind of things [advice about determining authorship]." Similarly, Dr. Webb and John have written multiple publications together and, although John's recollection of the authorship guidelines discussion was fuzzy, his understanding about appropriately including and being included is clear:

I think at some point we came to some kind of agreement, or we came to the agreement to come to the agreement, but I don't know if it's ever really been formalized. But if it is, you should tell them to tell me or something. But I know that if someone was at least marginally involved I generally ask them if they want their name on it. But I don't think we have a formal agreement or anything.

Core group membership. A final theme that emerged in Case Study One on terms of Organizational Values and Identity was who participants included when they referred to the team. At the beginning of my first interviews with Drs. Gunadi and Webb, they were careful to articulate that the team also included Drs. Krantz, Smith, and Davis. By midway through the interview, when they mentioned the group, they were referring to the five core members: Gunadi, Webb, and the three graduate students. A number of times throughout the interview, I checked my perception of what participants meant when they said *group* and in fact, they clarified they were really referring to the people most actively involved with the project. Discerning who Dr. Gunadi deemed the core group was relatively easy: when he referred to the core members, he tended to use only first names and when discussing the larger group, he would use people's full names and sometimes titles (e.g., Morgan Davis or Dr. Smith). Being on a "first name basis" with someone implies familiarity and, whether he realized it or not, Dr. Gunadi was telling me with whom he was most closely affiliated.

The graduate students in Case Two also discussed the team from the perspective of core group members and those who were less involved but, in most of those discussions, the students also included the partners from the university in the study country, participants in their own research, and also their dissertation committee members. Drs. Gunadi and Webb rarely, if at all, mentioned the partners at the overseas university and never mentioned any of their students' other committee members. That Anya does not separate her work on this particular team from her overall PhD experience became apparent during her interview: "I feel like that's everything I

do at BSU is related to this project." Also, although I prefaced my first discussion with her with an explanation that I was interested specifically in the research project she was working on with Drs. Gunadi, Webb, and the others, she asked me to clarify a number of times during the interview if I was asking about her dissertation committee. Similarly, she would give me answers and mention someone I had not yet heard about and when I would ask what that person's role was on the research team, she would tell me it was actually someone on her dissertation committee. Both John and Jenny mentioned their relationships with research partners at the study location's university and discussed the experience of getting to know those people.

Professional development opportunities. Interestingly, faculty participants reported having some unexpected learning as a result of their work on this interdisciplinary team. Dr. Webb learned about managing a grant and leading a team as a PI and also, as mentioned earlier, that he could rely on his graduate students for significant portions of the work. He said he and Dr. Gunadi do "95% of the work. Well, 95% of 50%" and that the graduate students handle the other 50% of the project and do so extremely well. He was pleasantly surprised at what the team could accomplish because of the contribution of the graduate students.

For Dr. Gunadi, learning has come from the opportunity to work with Dr. Steven Krantz, "I see [him] as a kind of a mentor to me almost. He's older. He's more experienced." Also, now that the project has been underway for some time, Dr. Gunadi has learned he would have been wise to include a data manager in the proposal budget. He spent a great deal of time during his recent sabbatical organizing and analyzing data, but there is more to be done and still more data that will be generated. He said that for future projects of a large scale, he will be sure to have a more comprehensive data management plan in place. As a result of receiving the NFA grant for this project, he has been given some opportunities for professional development he otherwise

would not have had: "to join [NFA Program Network] and to go to these different conference

and network with people outside of BSU on very related things to what I'm doing in [study

location]."

Anya mentioned that Dr. Gunadi has tried to encourage her professional development by

alerting her to opportunities she might be interested in and/or he thinks could be of benefit. She

echoed Dr. Webb's sentiments about relying on colleagues, "I've learned I can lean on my

colleagues a lot. I think I had this sense when I first came here of, you know, trying to be gung-

ho on my own about getting certain things done and [she realized] these people are here, you can

lean on them, you can use them as resources. So that was an important thing for me." Jenny said

working with the team has taught her how to be a better group member in terms of

communication, idea generation, and general optimism:

> Something else I need to work on but something I noticed and learned - it's important
> when you're working in a team, especially when you're talking about research questions,
> is just being open and optimistic - kind of following the rule of people who work in
> improv[isational comedy]. You're just supposed to say, "yes, and." You don't say, "no"
> to things. It's [saying yes, being positive] helpful when you're talking about research
> ideas and thinking about different things to promote discussion and to continue instead of
> saying, "No. No, no, no, that's not how...." You know? Not to be negative.

A significant point of learning for John during this project was how to navigate outside

issues to maintain momentum on his research, "The actual politics within the university I hadn't

taken into account. People have gotten involved and left the project and changed their level of

collaboration with me because of those things and I've kind of learned to take that into account

and to adapt to it when it does happen so that it doesn't impact the project."

Professional networking opportunities. Dr. Webb's professional network helped this

group come together. He made contact with Drs. Smith, Davis, and Krantz – each of whom he

knew in different capacities and also put out some information around BSU that eventually led to

Dr. Gunadi becoming involved. When asked about how working on the team had changed their professional networks, participants had varying responses. Dr. Gunadi's network has expanded and although he works well with the three doctoral students on the team and with Drs. Webb and Krantz, he would not choose to work with Drs. Davis and Smith in the future. Drs. Davis and Smith's have not communicated with their fellow PIs about why they have been less involved with the team, which has left Drs. Gunadi and Webb to assume the reasons are Dr. Davis's administrative duties and Dr. Smith's health troubles. The lack of communication from Dr. Davis and Dr. Smith has caused the group frustration and has made the work somewhat more difficult. Through this team Dr. Webb incorporated Dr. Gunadi and the three doctoral students into his professional network. His relationships with those four colleagues are excellent and he would continue to work with them, if possible, on future iterations of the project.

The doctoral students from Case One discussed network expansion in relation to their work on this project and to their dissertation committees and other meaningful contacts they had made during their course of study. Anya specifically discussed her advisor, Dr. Gunadi's, approach to networking as "proactive" and that he often will refer her to colleagues if he cannot answer a question for her. Similarly, a member of Anya's dissertation committee made it a priority to help her network more and had plans to introduce her to several colleagues and connections while the two were attending an international conference together. Jenny and John's networks have also expanded to include the overseas partners because they have spent the most time in the study location. Anya, having come into the project a year after the other students, will travel there again soon.

Assessing and supporting faculty work. Given the institutional context I described earlier in this chapter, Drs. Gunadi and Webb confirmed that grant-getting is a key component of

how their performance is evaluated. Dr. Gunadi experienced a significant shift in his work orientation when he arrived at BSU. Prior to coming, he had imagined he could continue his initial lines of inquiry, which required minimal field work and did not necessitate external funding. He was mistaken:

> So my first few meetings with <department chair> were kind of an awakening for me. Probably I was naïve. I walked into a faculty job thinking I had to publish and this was probably enough to get tenure and <department chair> made it very clear to me that publishing was part of that, but getting external dollars and getting graduate students were equally or maybe more important than publishing. So it kind of reoriented the way I looked at research I was going to do, and that's why I started going after grants early on. The department chair essentially said, "you gotta do this to get tenure." So I applied for 30 or 40 external grants my first four or five years here. It was a lot. Not all big huge grants, but many of them are. So, that sort of redirected my incentives a little bit. So I've got to get the external funding, which is the only way that graduate students are supported [in his department] - through external dollars. So that redirected my work.

> Because Dr. Gunadi is cross-appointed, I asked how that influenced his reappointment, promotion, and tenure (RPT) situation and how his work is evaluated and by whom.

> <Social science department> was my tenure home so in some respects, the criteria for tenure leaned more heavily toward the criteria at <social science department> rather than <STEM department>. But <STEM department> could've said, if I didn't work out, "No we don't want him." That would've jeopardized my prospects for tenure. <Social science department> may have said, "we like him so much we're going to try to re-juggle his appointment a little bit to make it work." I think it would've been really detrimental to getting tenure if one or the other didn't like me particularly <social science department>; if they didn't like me it was probably over. If <STEM department> didn't like me there may have been something that <social science department> could've done.

To achieve tenure, Dr. Gunadi juggled RPT criteria from two vastly different departments. In the STEM department, where he is appointed, interdisciplinary collaborative research is the norm and is expected, it "is just what you do." In the social sciences department where he is also appointed, and where his tenure home is, interdisciplinary research may have been risky for him:

> I think there's a norm in <social science field> and in <his branch of social science field> in particular, of being the sole author on a paper and if you're not sole author, your

contribution is sort of diminished. Not the case at all in the natural sciences, I don't think, but it is here. So, I had mentors say something - [they]made that comment. I published enough I don't think it was a concern but they thought I might receive some feedback from committees evaluating my work for reappointment or tenure suggesting that a co-written piece was not the equal of a sole-written piece.

Unlike Dr. Gunadi, Dr. Webb is appointed in two places that value and reward interdisciplinary research, "I think both units are very supportive of interdisciplinary research and recognize that the 21st Century issues we're dealing with really do require an interdisciplinary approach and a broader framework than just looking at <topic areas> but looking at how those two are related." He went on to say, interdisciplinary research is "rewarded and I think somewhat recognized as groundbreaking and kind of the next step for where research is going."

Both places where Dr. Webb is appointed see interdisciplinary research as the norm, which may explain his positive-sounding response when I asked how interdisciplinary work is viewed in his departments:

[They] want people doing research and recognize that on a 25% research appointment a lot of times you can't have your own full research lab going. So that's <STEM department one>. <STEM department two> is great in that they, especially in joint appointments like mine where it's kind of this minority appointment, they recognize there are often people that do research on larger teams and don't have a full-fledged research lab of their own. Both units are very supportive of the research even though it's collaborative.

Dr. Webb explained one way faculty are supported is through a policy enacted by one of his departments which, for RPT purposes, recognizes papers written by a graduate student as lead-author papers for that student's advisor. The policy "prevents professors from telling their grad students, 'even though you did all the work I'm going to be first author because I need this for my career.' It's a mechanism to prevent faculty from taking advantage of graduate students for their own self-gain" (Dr. Webb).

Factors Outside of MFIRC

The following section discusses each of factors that emerged after I used interpretive coding (Miles & Huberman, 1994) with my data. The emergent factors from Case One are as follows: administration, funding and resources, leadership, organizational politics, and place.

Administration. An issue that repeated itself in Dr. Gunadi's interview was his struggle as a first-time PI on a very large grant, "I felt like I had instantly gone from being research-oriented as a graduate student to being an administrator of grants as a faculty member." Similarly, he mentioned things he would do differently for future grants including budgeting for a data person and having a better, more comprehensive data plan in place. He summarized his experience with the administrative side of things this way:

I think that the limitations or the constraints of my particular project are less due to interdisciplinary problems than they are just basic kinds of administrative logistic kinds of problems. Things you learn from doing grants again and again and again and things that you could improve the efficiency of you know – how your organize your time, how you organize tasks, different people that you bring in to do different things associated with carrying out your research.

Of the entire project including grant-writing, working with a large team, doing research in a country where he does not speak the language, and having two co-PIs basically disappear from the project, his largest struggles are with the administrative pieces of the work.

Funding and resources. One issue related to the allocation of funding and resources arose during my interviews with members of Case One. Unlike External Attention, which is the portion of the MFIRC focusing on influences outside the group, the following excerpt describes a problem or frustration Dr. Webb faced after the money had been awarded and the group had made its budget allocations for the research project. In this case, part of the funding the group received was to be allocated toward covering salaries for faculty who are not paid over the summer months. Dr. Webb explained that

Different people draw different salaries. Krantz only gets 5% of his salary from it [the grant]. But for example Morgan [Davis] gets more in summer salary from the grant than I do because her salary is so much higher. She gets one month of $120,000 and I get one month of $65,000 and it just works out to different amounts. So in some ways she gets paid a lot by the grant and Gunadi and I haven't been thrilled with how much she's contributed to the grant. So that's kind of a little source of conflict that exists.

Although it is Drs. Webb and Gunadi who are making all the decisions about operational expenses as the research progresses, the salaries piece was sorted much earlier in the process, certainly before Drs. Smith and Davis faded from the project.

Leadership. The leadership on this team clearly rests with Drs. Webb and Gunadi. Both referred to each other as equal partners who share responsibilities for project direction, decisions, and graduate student advising. Dr. Gunadi said, "I don't know if we had a conversation between the two of us about how we would share grad students or whatever. I think we had such a relationship that we weren't concerned about how we divvy that [resources and graduate students] up just that we would have come to an understanding and I think it's just been that way."

The graduate students on the research team also see Webb and Gunadi as the project's leaders although they tend to communicate more with the one who is their main advisor. The graduate student Dr. Webb initially brought in landed on a research project more aligned with Dr. Gunadi's interests and vice versa; Jenny worked closely with Dr. Gunadi and John works closely with Dr. Webb. Given the "natural break" between the natural and social sciences, Dr. Webb leads the STEM efforts and Dr. Gunadi the social science efforts, but in terms of overall project direction, decisions are made jointly by Drs. Webb and Gunadi, often in consultation with the doctoral students during meetings. When the students were determining how to carve out their own part of the research for their dissertations, Dr. Gunadi said, "I told each of them from *the* start that I could be as big a presence as they wanted me to be in terms of guiding their

research." In the end, rather than use data already collected, each of the students decided what they wanted to do "in terms of data collection but relating to the larger goals of the project." The doctoral students confirmed that Dr. Gunadi, and also Dr. Webb, are supportive, available, and helpful leaders.

Organizational politics. In analyzing the data, I found some instances where participants reported situations required navigating. The circumstances discussed by the participants were not major nor disruptive but they did force some critical thinking and strategic analysis to determine how to proceed. I coded things like this *organizational politics* and three instances presented themselves during transcript review.

First, NFA regulations limit PIs on a project to one main PI; anyone else must be listed as co-PI. Although they lead the project equally, Dr. Gunadi is listed as the PI, which then gives Dr. Webb equal billing along with Dr. Krantz, Dr. Smith, and Dr. Webb. Fortunately, Dr. Gunadi and Dr. Webb's relationship is such that the disparity between their roles in the eyes of the NFA did not cause problems or affect Dr. Webb's career in a negative way. Being PI on a large NFA grant is an ideal credential to have in one's RPT portfolio especially for someone like Dr. Webb who is cross-appointed in two STEM departments (unlike Dr. Gunadi who is cross appointed to STEM and social science). The grant was a boon for Dr. Gunadi who said his name recognition increased substantially across campus and as a result, he has been invited to participate in projects for which people otherwise might not have thought of him.

The second instance of organizational politics was presented by Anya who said she had trouble determining some of the not-so obvious or unwritten parts of working with the group and what "the hierarchies are in academia." We discussed a particular incident where she had requested financial support for an aspect of her research. Something happened on the project and

some money was freed up but rather than allocate it toward her funding request, the money was used elsewhere. In that instance she was disappointed but was unsure if it was appropriate to question why or express frustration. "There's always a lot of things to navigate as far as what's appropriate - the rules you have to follow - so I think it took me some time to sort of readjust to that because I'd been out of academia for a few years" (Anya Fraise).

The final excerpt in the organizational politics category comes from John, "It's been kind of a learning experience to see how the group has changed throughout time due to things like politics or interest in the project and you know, I've kind of learned how to evolve based on those changes to keep my own, and research I'm involved with for the group, going forward." When I asked John what he meant by politics he said determining who would be (a) interested in a particular issue and (b) likely to respond so he could get answers and move forward. Eventually he determined who key players were and went straight to them for answers and no longer included extraneous members on emails or requests. His decisions were not intended to circumvent the wishes or instructions of the PIs. Rather, once he realized certain people in the study location revolved through roles quickly or that Drs. Smith and Davis were unlikely to increase their involvement, he no longer asked for their assistance or input, which expedited receiving answers to questions and helped him maintain research momentum.

Place. How the group connects with each other featured prominently in my interviews. When analyzing the data, I thought about issues of connectivity and geography and determined that I would use the code *place* to indicate passages that related to group members being physically together.

The team from Case Study One is geographically dispersed across campus and also across continents when the doctoral students are doing fieldwork. As discussed, their primary

method of communication is email and sometimes Skype. Dr. Webb and John are in touch multiple times per day via email and Dr. Gunadi communicates with Jenny and Anya almost as frequently. Email keeps them abreast of what is happening with the project but its capacity to facilitate larger group discussions is limited. In times when the group wants to meet to talk about something, they use Skype, which allows for real-time interaction as well as video options for when visuals are important.

Because the members are scattered around campus and at least one usually is in another country, I wondered how not being together might affect their cohesiveness. The team from Case Study One has traveled together to the country where the research takes place. They have gone together as a group and have also traveled individually. Both Jenny and John have lived in the study location for six to nine months at a time. Dr. Webb worked in the study location for over 20 years prior to beginning this research project. Similarly, both Drs. Smith and Davis had prior experience in the region and also both spoke the local language. Having everyone together in the region, especially with the guidance of the PIs who had extensive experience there, helped everyone visualize what they were attempting to do with the overall project and also provided unstructured, informal time for the group to get to know each other. Anya was able to join a full-group trip to the location after she had been accepted at BSU but before her program of study officially began. She described the experience this way:

> That trip was extremely valuable for me because it was my first time meeting a lot of these people, visiting the research site, talking things through, figuring things out, bouncing ideas off each other. So I thought that experience was really important – I'm glad I did it. I wasn't sure I was able to do it at the beginning when they invited me on the trip because I was still working at the time, but it absolutely did shape directions for the future [of her research].

Case One Round Two

This section opens with a short paragraph of the origin of the term *muddling through* in this study and then goes on to report the findings from Case One's second interviews.

Muddling Through

In round one, I asked my participants if they had been trained to do interdisciplinary work and most people, across all cases, said they had not. In fact, many laughed when I asked that leaving me to respond, "I'll take that as a no?" They went on to explain they had had to "figure it out" or their experience was "trial by fire" or they had "muddled through." I had a descriptive code for training but had not considered "muddling through" types of language throughout the rest of the interviews. So, I went back to look for evidence of people being faced with ambiguity and what they did about it. I found it interesting that on multi-million dollar grants, researchers were "muddling" so during the second round of interviews I asked, "Participants in my study reported muddling through, trial and error, and trial by fire. How accurate a representation of your experience is that?" I followed up by asking, "How much is the muddling through an important part of the process? How much do you think a team could benefit from training in how to work in an interdisciplinary group? What is to be gained or lost through training?"

When asked about muddling through and whether that was reflective of her experience, Jenny said, "I don't know if we were muddling – I'm not sure if that's the word I would use." She also acknowledged that as a graduate student, she was more intent on attending to her research than considering what was happening overall within the group, "so really my focus was not so much on fine-tuning communication and team building for doing this type of research. I just wanted to get my work done." Unlike Jenny who was unsure whether muddling was representative, Anya said muddling through or winging it was "100% my experience." Anya is also intently focused on her own sphere of research so she associated some the murkiness with

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the PhD in general, "On the one hand I think there is a little too much of just, 'here you are figure it out.' I understand we're doctoral students – the handholding is over. But at the same time, sometimes it does seem like this is structured to make the process as miserable as possible." I asked if she meant the doctoral process or the interdisciplinary research process and she said, "No, I guess I'm referring more to the entire PhD experience." So for Jenny, she did not notice muddling because she was focused on her realm of the project whereas Anya's perspective was influenced by the inherent ambiguities of being a doctoral student.

John said, "in terms of designing research/analysis and academic debate regarding a project, muddling through is an extremely helpful part of the process that is important for team building." Team building and team dynamics were an important consideration for Dr. Gunadi who mentioned them several times during both of my interviews with him. Part of the muddling for him involved putting the team together in a certain way:

> I think the team dynamics, the best way to organize teams to be productive, how you facilitate productive relationships, productive meetings – I don't think you can learn just by consulting with people who've done it necessarily or reading outside literature or whatever it is. You just have to do it because I think your reactions are kind of dependent on who you are right? So some of the best ways to muddle through are not likely to be the same ways that other people use – you kind of have to find those ways yourself.

I asked if there were other things Dr. Gunadi might have wanted to learn more about in terms of leading an interdisciplinary group:

> I can see the value of it [training]. In the particular case of my project I don't think it was the key stumbling block but it would help. Training would help but I don't think it was the critical piece. I'm not saying the project was not successful or anything I'm just saying if I had to re-do any part of the research project again, that wouldn't be my first choice is to choose interdisciplinary training; it would be thinking harder about the logistics and the administration of the grant - more the day-to-day details.

John was not strongly in favor or against training for interdisciplinary teams but did have some practical ideas for what training could entail and which sound similar to some of the day-to-day

things Dr. Gunadi mentioned. John suggested training "would have to be an abbreviated affair" because people are "generally extremely busy" and said "teams could surely benefit from training in how to work interdisciplinarity. I think in this scenario, the most helpful training would be a workshop helping co-PIs to get more organized in their collaboration and giving them templates for agreements on data-sharing, organizing group meetings and activities, and for sharing project responsibilities." I asked Dr. Gunadi about how PIs go about learning those administrative or day-to-day things and whether training is available for them. Aside from learning by doing, Dr. Gunadi said,

> I think I've had opportunities to engage in interdisciplinary training and I've sort of said, "things are going alright in my groups and I think we get along quite well and it's sort of about interacting with people in a common sensical [sic] way. Treat people with respect and try to communicate well." I know those things so I'm not sure what good training would do me. But that's before even seeing what the training is so that's a weird stance. I fully admit that.

> In the following passage, Dr. Gunadi talks further about training for interdisciplinary

teams and speculates as to why people might not engage:

I think a lot of people's perspective on a lot of things is that, "I read to figure out what to do then I do it." But for some reason I think in this area [interdisciplinary collaboration], a lot of people think that this is kind of common sense stuff and therefore don't really need to read expert opinion on this. They think, "I can just figure this out and it's [training is] a waste of time." So in some ways it might be a kind of a rationalization: because I've decided that I don't need to do this, that's going to be my answer is that muddling through is indeed the best course of action because that's the choice I've already made and I'm rationalizing my choice.

For Dr. Gunadi, it seems like the things he would have appreciated learning about ahead of time were not the things he anticipated (e.g., administrative hurdles) and that what has been offered to him in terms of training has addressed things he does not see as problems within his group.

Networks

Before reporting Case One's findings, I provide some background on the nature of the question I asked participants. As I analyzed round one interviews across cases, that my

participants' groups were founded based on someone's professional network became clear. My finding was not surprising; the value of networks is well documented in the literature, hence the inclusion of Professional Networking Opportunities as a sub-factor in the MFIRC and an interview question about how someone's professional network influenced the formation of the research groups. The PIs in my study tended to know each other from prior projects or knew someone who connected them to another researcher. Basically, people relied on their networks. In one instance, a co-PI was brought on after being found via an Internet search. Given the importance of interdisciplinary research and the large problems it is intended to solve, it occurred to me that if researchers tended only to work with people they already knew, but that disciplinary silos exist, how would more multidisciplinary teams come together?

When asked how they would find experts to work with in the future, participants from Case One all said they would first look to their own network and then the networks of people they knew. Anya said she would look to her closest colleagues at BSU including members of Case One, her committee, and colleagues she has met on other projects. She would extend to her network at her former institutions and the networks of those people too. She said, "So I guess I would always try to go through existing connections and people I know." When I asked why she said relying on networks has been effective when she has had to do so in the past. Similarly, Jenny explained she would also rely heavily on her own network and the networks of others she knew and trusted: "You want to know the person's skill level based on someone's who's dealt with them before. So if I didn't know somebody directly, I'd ask the people I know and trust, who do excellent work, about their experiences." John said he would be willing to work with someone he did not know but only in a scenario where the group already had others of his close collaborators.

The issue of putting together a research team is one Dr. Gunadi has thought a lot about. During one of our talks he said the following:

> I think the way that we assembled the team was problematic. It was mainly because of Dave's contacts. It wasn't seeking people who we thought were the best fit for the ideas that we were trying to get at. In retrospect, we could've picked some people within [social science field] that would've been better fit with the kind of research that we had planned. So going forward I'd be much more careful in how I select people. Dave was kind of leading that effort because I didn't know anyone at BSU; partly it was new to us – he was young. I was young. We had never assembled a team like that we had never really thought about fit.

Knowing that Dr. Gunadi has some regrets about how things have unfolded with the extended members of Case One, I asked how he might assemble a team in the future. He shared concerns about going outside of his network and the influence doing so may have on the group, "I think it's the noise you potentially introduce into the functioning of the team." His concern is that the person "would be disruptive to others' productivity somehow." He walked me through how he might find a new collaborator in the future:

> I think Plan A is to figure out who I've worked with in the past or figure out if that expertise [he requires for the team] matches with anybody that I've worked with in the past. Then it probably goes to an extended circle where I'd consult with people I've worked with, people that I trust, to figure out if they know some people that I don't know to get their assessment of somebody's expertise and their ability to work in teams and that sort of thing. It would probably be rare that I would go to the next stage where I'd cold call someone where I know their expertise [but not their interpersonal skills, work habits]. I think if I'm going to do that, it would be someone that I've been familiar with that I've met a few times. The very last on the list would be just someone that I know from the literature that has an expertise that would be perfect but I've had no interaction with and we know nobody in common.

I found Dr. Gunadi's response interesting because in the first long quote, he talks about finding a person with expertise that "fit" the main ideas or goals of the research. In the second long quote, however, "fit" seems to be more about how the person can interact and be productive and less about the expertise. If one is concerned only with expertise, the first avenue to find someone might be to search the literature on a given topic. Rather, Dr. Gunadi explained an exhaustive

protocol for finding someone with knowledge but about whom he also has broader information on work habits and interpersonal skills. The graduate students on Case One also highlighted the importance of colleagues' interpersonal skills and expressed wariness about working with complete strangers. Anya said her experiences in the past have taught her to rely on her network to find new connections and John said he would work with someone new only if the new group he was forming also had a member from an existing team he belonged to. Jenny did say she would work with someone unknown to her but only after she had exhausted all possible connections through existing contacts.

Integration

During the first round of interviews, I asked how decisions were made within the group around allocation of work, resources, and credit. I wanted to understand *how* decisions were made rather than whom was given what. Responses sometimes included mentions of divvying up work along disciplinary lines. When I re-looked at the data across cases, I noticed additional mentions of disciplinary-based decisions so I looked for patterns and found a number of passages suggesting separation of disciplines rather than integration. I wondered how work, if at all, was moving from disciplinary specific to integrated. As such, I drafted a question to elicit how participants viewed their team's work in terms of integration.

Dr. Gunadi is passionate about the integrative aspects of Case One's project. He expressed disappointment in the first round of interviews that some of the large, integrative papers have not yet been written but recognized that a final round of data collection is necessary before they can put out some of their synthesis work. He looks forward to doing so though and is confident the group can accomplish that:

> I think the integrative stuff is more interesting to me. There are a few reasons for that. My background, which I talked about last time, I tend to gravitate toward those questions and I think they're more interesting to a broader audience than some of the more narrow,

narrowly constructed questions are. The second thing is we were funded by a very interdisciplinary program from the NFA and in our promises to them, if you want to call them promises, we said that we would do these kinds of studies. I fully expect to fulfill those kinds of obligations I made when I wrote the grant. When I assembled the team, I assembled the team in a way I thought we could bring in those pieces and perspectives into one integrated whole. My interests, how I was funded, and things I said in order to get funding – those to me all point toward doing that work eventually when we're ready to do it.

Jenny suggested the group was highly integrative, "I think we not only made a pie, we made a bunch of pies!" She went on to say the work everyone is doing involves "melding these different fields" so despite people doing their individual bits, everyone is drawing on interdisciplinary resources and disciplines to accomplish the work.

John supports the idea that both assembly and integration take place within large projects:

I don't think the two approaches are mutually exclusive and in many cases I think it is necessary to combine both approaches. For instance, we have several PhD projects as a part of our overall research efforts. These are stand-alone efforts that will produce papers on which not all team members are co-authors.

The responses from participants on Case One suggested there are times when the work has been integrative and times when people have had to do their own disciplinary parts. As the last of their data are collected and analyzed, the team will have a better idea of how the larger, multi-disciplinary picture will come together and Dr. Gunadi is excited for that phase of the research – when he can begin to address the broad, multi-disciplinary questions.

Case Study Two

Three faculty members, eight students, and an outside consultant comprise the research group from Case Two (Table 3). Two of the faculty members and three of the graduate students agreed to participate in the study. The outside consultant is a public servant, acts in an advisory role, and does not actually conduct any of the research. As such, she did not meet the eligibility criteria for this study and I did not invite her to participate. The two undergraduates were not invited to participate in this study because they did not meet eligibility criteria.

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Membership in the group changed from the time they received their first grant to the time I interviewed them midway through their second round of funding. Social science doctoral student Mike Myers and STEM Master's student Lonnie Elamb both graduated around the time the first grant ended. When the second round of funding was awarded, Laurie Stroud replaced Mike Myers on the team but Lonnie Elamb was not replaced. The other graduate students chose not to participate in my study.

Dr. Loomis is a tenured associate professor in social sciences and Dr. Wynn is a tenured professor in STEM. They collaborate on one project together and co-wrote the first and second grants that support the research I interviewed them about. Dr. Simms was brought onto the team for the second grant after a partnership with a different STEM professor during the first grant period failed to produce the findings the group was hoping for. Drs. Wynn and Loomis adjusted their approach to the research and invited Dr. Simms, renowned for his skill in a particular STEM area, to be part of the team. Three PIs are located on campus: Dr. Simms and his student are located in one building and Drs. Wynn and Loomis work in a building, and have offices in the same hallway as each other, across campus from Simms and his lab. The fourth PI, the consultant, is not an academic and works in another city close by.

The group came together because of serendipity. Dr. Wynn has expertise in two STEM areas and has held a number of appointments in different departments around campus. He is a self-described "lone wolf" who does "not like to be told what to do" and therefore has had several "fallings out" with various department heads over time. For the past several years, he has held a joint 35/65 appointment in two STEM areas: one where his tenure home is and where he teaches (35%), the other where his research lab is located (65%). After shuffling around, he landed in a department (his 65% department) one would not normally associate his training with.

That same department happened to be physically located in the area where Dr. Loomis' office is. As the two spent time working in proximity to one another, they got to know each other and Dr. Loomis would ask Dr. Wynn his opinion about cases from time to time. Eventually, the two decided to collaborate on a project incorporating Dr. Loomis' specialty, the two areas Dr. Wynn works in, and a third component involving another STEM collaborator from Haddonfield State University. Although the first grant produced meaningful results, the group was not able to achieve their main objective. For the second grant, they changed how they approached one of the STEM components, recruited a new collaborator (Dr. Simms), and at the time I interviewed them, the group was mid-way through their second phase of funding.

Table 3

Case Two Research Group Members

Participation	Name	Position	Field
Round 1	Lonnie Elamb	Master's Student	STEM
Round 1	Sam Loomis	Associate Professor	Social Science
Both Rounds	Mike Myers	PhD Student	Social Science
Both Rounds	Laurie Stroud	PhD Student	Social Science
Both Rounds	Terrence Wynn	Professor	STEM
Non-Participants	Bob Simms	Professor	STEM
	Consultant	Non-Academic	STEM
	Student 4	PhD Student	Social Science
	Student 5	Master's Student	STEM
	Student 6	PhD Student	STEM
	Student 7	Undergraduate Student	Social Science
	Student 8	Undergraduate Student	Social Science

External Attention

External attention was a factor in this group in two ways. First, the group is required by their funding agency to submit two progress reports per year. As such, the team structures their work to coordinate with those deadlines and, as Dr. Loomis said, "those keep you on task." When, during their first grant, the group's work took longer than expected, they were granted an extension so their two-year project took three. The current project is about mid-way through so the group is unsure yet as to whether or not they will need another extension.

The other way this research team is influenced by external attention is that their "funder really cares about deliverables" (Dr. Loomis). Dr. Loomis said the group's work is "foundational" in that they are trying to create a new method to identify a certain phenomenon. The work is "really cutting edge stuff," according to Dr. Loomis, and his group is somewhat challenged because although the research is innovative and somewhat exploratory, the funder still expects a deliverable, or something "applied" (Dr. Loomis). Knowing they are responsible to produce an applied deliverable influences the scope of what the group or how much time they can devote to exploring ideas.

Systemic Implementation

Each of the five systemic implementation sub-factors within the MFIRC played a role in this group's experiences. In the sections that follow, I describe how my participants responded to questions about each of the sub-factors.

Assessing and supporting faculty work. Members of Case Study Two raised this sub-factor repeatedly. First, I will discuss how the social science doctoral students are influenced by this sub-factor, and then I describe what Drs. Wynn and Loomis had to say about assessing and supporting faculty work.

Influence on doctoral students. Although this sub-factor is titled Assessing and

Supporting Faculty Work, I discovered that the social science PhD students in Case Two face the

same pressures as faculty do in terms of productivity and funding. Mike described, and Laurie

confirmed, the funding situation in their department at BSU is based loosely on a points-type

system. So, unlike many other graduate students who are accepted with a particular funding

package (e.g., two years of funding, a five-year fellowship), the students in Mike and Laurie's

department are assessed on an annual basis and ranked in order from most to least productive.

The best funding package is awarded to the most productive student, the next best funding goes

to the next best student, so on and so forth. When I asked how research was rewarded in his

home department and how collaborative versus single-authored work is perceived, Mike relayed

the following story.

> There was one year where I think, let's say, I published two articles and had three
> coauthors on each article. Let's say you published two articles but on each article you
> were the only author, so they [department administrators] said, "we have a tie between
> these two people" and they would've given you the funding because you published by
> yourself. Which I personally disagree with but whatever, who cares.

I asked Mike if the policy his department enacted was communicated to him or available

in print and he said the following:

> It was tacit. I don't think it was written down anywhere. I think, it happened pretty rarely,
> but I remember it did happen the one year. So, that's the only reason I probably even
> know about it because I was like, "I did a lot of work this year why was I ranked second
> compared to somebody else? And [he was told], "oh because he [other student] had this
> one thing that he published by himself." I was like, "well, that's stupid."

Laurie seemed unaware of her department's hierarchy of single- versus multi-authored

work: "To me as a grad students one of the biggest rewards is going to be financial – are they

going to fund me? We do get more financial rewards if we're doing research, if we're presenting

research. Whether or not it's interdisciplinary doesn't really matter, it's not weighed any

differently." Laurie went on to say she thinks her department is supportive of interdisciplinary

studies and "it's encouraged. She then said, "whether or not it's rewarded over individual research, I don't know if it really is." The mismatch of information between two students from the same department, who worked on the same project, and who are friends with each other is interesting and suggests expectations have not been clearly defined for or communicated to at least some of the doctoral students in Mike and Laurie's department.

Influence on faculty. Being awarded the first grant was important for Dr. Loomis' career. He was pre-tenure when the project was initiated and was tenured shortly after he got the grant: "you know getting a big grant helped that go through much more smoothly. I mean, you know that, right?" (Dr. Loomis). Dr. Loomis's college has been pressing faculty to engage with STEM, "I think that the hot button word over the last decade has been *STEM research*. I think the reason STEM research is so attractive is that it has the ability to bring in the big money" (Dr. Loomis). He went on to say faculty are rewarded for publishing but, "what the real reward is, is if you bring in big money. That's the best thing you can do. Right now the atmosphere at BSU is big money is more rewarded than publishing." I asked Dr. Loomis if he was worried, as a pre-tenure faculty, about putting so much stock in a large, interdisciplinary project. He said he was aware it could be dangerous for untenured faculty to do interdisciplinary work but that in his department he did "not get dinged" for being second or third author on publications but was clear that he also had several first author publications to his credit.

Dr. Wynn faces different pressures than Dr. Loomis. Wynn, a senior researcher, is near the end of his career and said, "this isn't my time. It's their time." As such, Dr. Loomis is listed on their current grant at the primary PI and Wynn and Simms are co-PIs. Over his career, Wynn has had millions of dollars in funding and, whenever he has a falling out with a department, fairly easily moves to a new one because the chair is usually interested in the grant money that

accompanies him. He offered two such examples where he changed departments, once because

he did not get along with the chair and another time because the chair, after a few years, still did

not know Wynn's name when they saw each other in the corridor. That irritated him, so he took

his funding and went to a new department who happily accepted, him "even though I don't fit in"

because "they're trying to build their research database – they want more and more people doing

research so I fit the bill there" (Dr. Wynn). So, despite having brought a lot of money initially,

Wynn's current chair is "upset" that Wynn is "not the PI" on the project with Loomis. When I

asked why, he said, "because the primary department gets most of the indirect dollars and most

of the reward is coming from that. If I'm not the PI, even though he says it's alright that I'm

doing what I'm doing, it's very clear that he would rather have me be the PI on the project

because it's better for his department. One of his missions is to build their research and if I'm

doing research but Loomis is the PI, that doesn't help him [the chair]." Unfortunately for Wynn's

department chair, Wynn is getting ready to retire and is also transferring PI responsibilities on

other projects to co-PIs. If Wynn's chair wants to increase his department's research portfolio, he

is going to have to find a new funding superstar.

Organizational values and identity. The people in this group reported having

productive working relationships with other members. Mike said he got along with Dr. Wynn's

Master's students and that they "were good guys" but that he has not kept in touch with them

since the grant ended. Dr. Wynn said, of everyone who has been involved with the grant, he had

worked most closely with Mike because they spent so much time together conceptualizing the

experiments and discussing initial findings. At the beginning of the first grant, it was really the

two of them, Wynn said, who were always on the project. Dr. Wynn said he does not work as

closely with Laurie as he did with Mike but that is a result of the phase of the project they are in

more than anything else. Laurie came on to replace Mike and Lonnie Elamb and the other Master's student were already graduated or were transitioning out by then. She is now the senior student on the project and said,

> It's kind of been nice and open and everyone works really well together and plays really well together so there have never been any disagreements really or huge blow-out arguments where people aren't talking to people or anything like that. It's been a really pleasant work experience. Has everything gone smoothly? Not always, but people are willing to work it out.

Dr. Loomis was grateful for the fortunate placement of both his and Dr. Wynn's office and their relationship that has developed over time: "there's a real affinity with that lab. We have formed friendships over the years, you know, we…we trust each other. We'll go for advice from each other. It's really an ideal setup. We're very lucky." In terms of Dr. Simms's lab across campus he said, "we've really grown to clearly respect their work and really like the people we're working with but we don't see them on a daily basis. It's not as close-knit."

I found this group's norms for interaction interesting. Laurie is in contact with the partners on a regular basis: Dr. Wynn, her advisor Dr. Loomis, Dr. Simms's graduate student, and the outside consultant. Meanwhile, Dr. Wynn said he has not "talked to Simms in a year, probably" and is really only in contact with Dr. Loomis because they're physically located near each other. Similarly, Dr. Wynn and Dr. Loomis have different ideas about the group's priorities and rather than wait for Loomis, Wynn said he plans to move forward on his own. I asked about the situation and whether or not he has communicated his concerns to Dr. Loomis:

> Well I say that [they ought to focus on publishing] but it really doesn't go very far right now so I'm really just doing my stuff myself. I see it as being important. I'm not so sure Sam does – he's got his mind set on this other thing.

Dr. Wynn has mentioned his concern a few times but he has seen no movement on the part of Dr. Loomis to address it. Rather than push the issue, Dr. Wynn is forging ahead and will also move forward with any associated publication(s) resulting from this part of the project.

Unfortunately, Dr. Loomis did not respond to requests for an additional interview so I did not have the opportunity to ask him about Dr. Wynn independently tackling experiments or ask Loomis what, if anything, that meant in terms of the group as an organization or its cohesiveness.

Professional development opportunities. The experiences described by my participants from Case Two fall into two categories of professional development: *learning* related to the work, which also includes how to work in an interdisciplinary fashion and the *benefits* that can come from interdisciplinary collaborations.

Learning. Aside from learning details and practices of each other's fields, the participants also learned how to conduct interdisciplinary collaborative work. I asked people how much experience they had with interdisciplinary work or whether they had been trained to work on a multi-disciplinary team. Dr. Wynn, as stated earlier, is a self-described "lone wolf" and prefers to do things on his own. He learned to do interdisciplinary work by waiting until late in his career, having prominence, and working with faculty who are more junior than him. He described a few other collaborations he attempted with people he considered peers and they did not go well. Wynn was quite candid that he prefers to be in charge and "call the shots." Working with Dr. Loomis gave him the opportunity to explore an interesting research area but also be the most senior researcher on the team.

> Laurie said her experience on the team was "baptism by fire." She explained,
>
> You can understand the principles of interdisciplinary studies and research but I don't think there's necessarily a training you could go to and be an expert on interdisciplinary studies. I think it's always going to be different. It's always going to be baptism by fire. You're always going to be working things out.

Although doing the work challenged her, she also said that interdisciplinary collaboration

> is a beautiful form of research because you're opening avenues where you're admitting this is not my expertise. One of the principles is letting that guard down and embracing others' expertise. Understand there's give and take. You're going to be wrong more often

than not or not understand things but if you walk in knowing that and you're willing to learn and everyone else is willing to play ball, it can go smoothly.

Laurie also said as a result of working on this project, she is more confident about working on multidisciplinary teams in the future or even writing her own interdisciplinary grant proposal. Mike and Lonnie both said they learned a lot about working with people from different fields but Mike also said, "I learned it's easier to work with other people if you can just figure out ways to divide up the work." Unlike Laurie who considers herself the "translator" for the group and who values having all the students together on the same floor so they can work more closely together, Mike's approach was to determine how to divvy up tasks in order to facilitate progress. He worked closely with Dr. Wynn and Lonnie Elamb but, in the end, found it easier to do so only as much as necessary and do whatever else he could on his own.

Benefits. Dr. Loomis was clear about what this project has done for his career. The work the team does has national prominence and is about a sensitive topic that easily makes headlines. Dr. Loomis said, "the outcomes of this work have provided me much more prominence in my field than I had ever imagined. If I were continuing on my initial trajectory, I would've been doing fine. But this? This is big work. It's important work so it has accelerated how I'm perceived in the field." He also went on to say,

> the contributions you can make to your own field are huge when you work multidisciplinarily because what you bring is all of these new ideas from these other sets and that's what pushes a field forward. So, when I talk about advancing the frontiers of the science, it's this kind of project that does it. It doesn't happen very often.

The other members of the team echoed Dr. Loomis's feelings about the contribution they are making both to science and to society. The subject of work is intense and is relevant across the globe. Being part of something so significant made all of the participants I spoke with from Case Two feel deeply committed to the project and satisfied that their contributions may actually make a difference to society.

Professional networking opportunities. I asked Dr. Wynn, "what would've happened if you and Dr. Loomis weren't near each other?" and he said, "it never would've happened. No." The network that brought this team together formed as a result of BSU deciding to place Loomis and Wynn's offices in the same hallway. It was not always that way – when Dr. Loomis first started at BSU, the lab had just moved to its current location. Prior to that, it had been located elsewhere and the sorts of work and conversations Loomis and Wynn are able to have "just weren't happening" according to Dr. Loomis.

Having the opportunity to work with Dr. Simms and Dr. Wynn is important for Dr. Loomis. Dr. Loomis said Simms is a senior scientist who is "famous" in his field and successfully recruiting his lab to the project was a boon for the research. Similarly, Dr. Wynn is well known and his name added to the project. For the students, their networks expanded across disciplines and also ranks. They now can count their peers and also the PIs as people within their network. Whether or not they could call upon the PIs in the future in the same way they could their peers has yet to be seen. Laurie expressed that her network had expanded also to incorporate people in the outside consultant's field. The consultant is a gatekeeper of sorts to some of the data the group needs and Laurie was tasked with cold-calling many offices to request said data. Because of the sensitive nature of the project, her association with the consultant and Drs. Wynn and Loomis was helpful in convincing offices to work with her around the data. She fosters those connections she made during the data gathering phase: "We go to professional meetings where all those people are and they recognize me and say, 'Hi' and I usually buy them a beer or two to thank them for, you know, babysitting me. It's probably been pretty beneficial for me – hopefully I can drop some names and get a job eventually."

Communication and information technology. Communication among members of

Case Two tends to be in-person or via email. Because most of the team's workspaces are along

the same hallway, multiple, in-person communication events take place everyday. The team also

uses email frequently and according to Laurie, is good about including everyone on messages so

the entire team knows what is happening. She said he had not had an experience where others

had decided things and she was the last to know. The group also holds meetings and Dr. Loomis,

Mike, Lonnie, and Laurie all mentioned the value of bringing the team together. They all said the

meetings were helpful to keep everyone informed as well as serve as a venue to discuss

challenges or clarify things. Laurie said,

> I think things get lost in email a lot. You know, how do you explain statistical analyses
> through email? I don't want to do that. I don't want to write that email. I'd rather walk
> down the hall and say, "this is how a decision tree works or let me tell you why these
> variables are coming out the way they are." Sometimes it just makes more sense to do it
> in person than through email.

The other way communication emerged in this case was through references to language

learning and translation. For example, Laurie said:

> in the beginning everyone was speaking a different language. It was really frustrating and
> I kind of felt like somehow I became the translator between all these different fields. You
> know talking, trying to express my advisor's concerns or opinions or whatever to the
> others and vice versa.

I asked how she had become the translator and she responded:

> So I think it's just because of my experience and my ability, as opposed to my advisor's,
> to really delve into the other branches of what's going on. I don't like to not understand
> things so instead of just telling me "oh just trust me this is working," I want to be able to
> ask important questions and understand what those stats mean. So I taught myself a lot of
> things and asked the other grad students a lot of different questions to understand what
> work they were doing. So I think that's kind of given me an overall understanding and I
> can understand his [Dr. Loomis'] concerns but it might be difficult for a [STEM
> colleague] to understand. It's just kind of like whoever can convey it the best. I don't
> know, I just kind of fell into that position – probably because I'm a loud mouth too. I
> have no problem being that person.

When I asked Laurie how she felt about being the "loud mouth" she said it really helped her dive into the work, understand things, and ask questions because she is not afraid to drop the pretense of knowing things she doesn't. Approaching the work this way has allowed her to understand, at least to some degree, all the facets of the project and to get to know each of the team members. As such, she has found it easier to work with people because she experiences the group as one where "everyone works really well together" which has created "a really pleasant work experience." She was the only one of the participants from Case Two who spoke about the team in such glowing terms. She was also the only person who discussed putting in the work to get to know the people, their work, and the best ways in which to communicate with them.

Factors Outside of MFIRC

       Place. Place was the only additional factor that emerged independent of the MFIRC in Case Two. Place was critically important for the genesis of this research group. If Drs. Wynn and Loomis had not been co-located on the same hallway, they would not have met or started collaborating. Across the interviews, participants mentioned the ease of being located near each other and how that allowed them to bounce ideas off each other or pop down the hall to ask clarifying questions. Laurie mentioned that, between my first and second interviews with her, Dr. Simms's doctoral student had been given an office on the same hallway as everyone else on the project. Rather than being located in another building, he now occupies space close to the main PIs and his doctoral student colleagues which, Laurie said, seems to have made him [the doctoral student] happy and has really improved the speed and clarity of their communication between one another. I asked how Drs. Loomis and Wynn came to be located near each other. Dr. Loomis said, "I think the building made sense because the [lab] is here and we [Wynn and Loomis, among others] have [samples for the lab]. But this floor? It was just random. It's really

interesting in terms of decision making by a university, putting the right people on the right

floors."

Case Two Round Two: Muddling Through

The first participant I interviewed for a second time was Mike Myers from Case Two.

When I asked him about muddling through and whether he thought training could be beneficial,

he said,

> I guess for me, I liked it [muddling]. I felt like it was good – like it helped you not only understand the process but it helped to interact with that person and see not just how the process works but how their thought process works. It built the relationship because you're sitting next to them and asking them questions and kind of feeling your way through it with them. If you just were to read a [training] pamphlet or something, you're distancing yourself from the project in some way or the collaborative portion of the project.

> Similarly, Laurie said, "I'm a big proponent of you learn from your mistakes and you

learn how to interact with people better." She qualified her statement by saying, "As long as

muddling through is continuing to push you forward I think it is important. Would it be better if

you could hit the ground and all of you are running at the same pace? Ya. Is that practical? I

don't think so." Dr. Wynn is also supportive of trial and error:

> I always tell my people, "just do it and see what we get." Most people spend so much time planning and thinking so much that they end up convincing themselves they shouldn't even do it because there are so many negatives. So I always tell my people "forget about that" and, "this is what I want done just do the damn thing and we will find out, when you do it, what we should do next." So in many ways, maybe I am a muddler. You know, serendipity seems to always play a role in what I do because things just, it's research, things just – it's very difficult to plan research. Even though when you write a research proposal it's all planned – there's not many times when you get exactly what you think you were going to get. It just doesn't work that way.

> Laurie said something similar about the process of research; things do not always go well

but "that's research. That's science." The participants from Case Two seem to have a healthy

respect for forging ahead and seeing what happens. I asked what they thought about training for

interdisciplinary groups and whether it might be helpful. Laurie was dubious, "I think it would

be a difficult task to train someone to do an interdisciplinary study because to me it's training someone to play nice with others and be interested in other people's work." She went on to talk about how training might work to bring people who have been trained differently, not across disciplines per se, but across types of institutions and "what they preached. It really boils down, being able to work as a team with members that maybe you're not super familiar with at first."

Networks

Mike is not hesitant to cold call someone and invite them to collaborate although he would start with his network first, "I'd probably email a bunch of people in my network – a bunch of my friends. I might post it on Facebook or something because I have so many professional friends on Facebook. That's probably how I'd go about it. I've tried to email authors that I've read their articles and it didn't work." I asked what did not work about emailing people he found through the literature and Mike said his latest example was that the person was not available or interested in getting involved with the proposed project. I asked what separated him from people who are unwilling to reach out to people they don't know, "I guess people are maybe intimidated to do things like that. But to me, they're just people. You just email them. They don't have to respond. It's up to them. It's not a big deal. So it just seems to me like what you should do – it's not a big deal."

Laurie was confident she could find someone to work with through her professional associations which she considers part of her network:

> As a <major social science field> we kind of have one world but as a <social science sub-field> we kind of have another one. I feel as though I already have a good network in the fact that I'm a member of this academy of <social science sub-field> and there's a common courtesy there. Let's say I wanted to collaborate with someone and I was able to find they were a member of that group, I would probably call upon that. Or if I was fortunate enough to know someone who knew somebody – often I feel like researchers and scientists are going to talk about what they're doing and what their steps are and people are always saying, "I know this person, I'll put you in touch with them." In that

world we have a lot of contact already and it just kind of spreads further and that's kind of what you rely on.

Dr. Wynn is close to retirement and only recently began working on collaborative projects. As such, he is not interested in finding experts for new projects so he did not talk me through his process of going about finding people to work with. He did, however, describe the role he likes to play on a team and that is to be the person "in charge." "In my group I tell people what to do and they do it. If they don't, I get rid of them." As harsh as that may sound, he has built a very successful career by managing his work that way. He does value input from others though, "I can't say everything right all the time. I'm right sometimes not all the time. I like to have a little bit of feedback. But not much. I will admit to you – I don't like much criticism." The project Case Two is engaged in satisfies Dr. Wynn's criteria in that (a) it was his idea, (b) the team needs him, his lab, and his students to run the experiments, and (c) he had held large STEM grants before whereas Dr. Loomis had not so his administrative expertise was integral to the work too. Dr. Wynn's response about finding collaborators was unique – both Mike and Laurie both said they would look first for someone with expertise and Mike is willing to reach out to people he's never before met.

Integration

Dr. Wynn said this about integration: "I do my part and Simms's lab does his part and Loomis' labs does his part." I asked who would bring everything together in the end and he described the shift in leadership from their first grant to the second:

> Well, when you say bring it together I'm not sure what that means because we're all contributing to make it come together. I think on the first grant I was kind of the mentor of it. I collected the pieces. The second grant I wanted Sam to be that person so he collects the pieces now and makes sure the pieces come together. We have to do semi-annual reports so his responsibility is to put those reports together so he collects the pieces**.**

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Although Dr. Wynn described collecting pieces to bring the project together, Laurie's experience sounds different from that; when she described how the group works, I did not get the sense that people worked on their own disciplinary part in isolation and waited for someone to sew the pieces together in the end. She said,

> I think to some extent we are separate entities and that's a good thing because I don't understand anything about <STEM field> nor do I have any interest in spending a long time learning it. So yes, I want them to go and design the experiment but we do kind of have our fingers in each other's work and I think that's really where the strength is coming from. There is a lot of back-and-forth [between collaborators about the work] but in the same breath, when it comes to write our report we have separate sections – here's what this group did, here's what this group did, and here's what this group did. So, it is separate but we do dabble in each other's worlds a lot. So I think we're kind of in the middle of the pie analogy.

I asked Laurie if she thought there was a better end of the assembly versus pie-baking spectrum on which to be:

> It depends on what you're trying to answer. It depends on the problem you have. Now if it would work out that you have group X doing one thing, group Y doing another thing, and then headmaster Z can pull it all together and make sense of it and actually have it cohesive then okay. Would it benefit them to maybe work together? Probably. I think for me, any time I'm involved with trying to solve a problem I like to kind of be able to see all of it in some respect because I feel like that gives you motivation and understanding of what you're trying to work towards. But, you're an expert in your field for a reason. I don't think you should be an expert in all fields. There's no true renaissance man.

For Laurie, the extent to which she is involved in the work of her colleagues is related to her overall understanding of how the project is unfolding. For Dr. Wynn, he gives direction and expects a report from his "people" after which he will issue more directions. For Dr. Wynn, the experience must seem more like assembly of pieces because he is not the one doing the figuring-out. Laurie's experience, on the other hand, is shaped by having to act as the group's translator and having to liaise across all aspects of the project. For her, understanding everything seems critical and, as such, presented Case Three as a more integrative project than Dr. Wynn sees it as.

Case Study Three

The team from Case Three includes six faculty and one postdoctoral fellow (postdoc). Table 4 illustrates the team, their roles, and their disciplinary home. When I interviewed the group, they had recently submitted a proposal to NFA so, although the team has been together for about two years, they have spent that time writing grants and have not yet engaged in the research they proposed.

Table 4			
Case Three Research Group Members			
Participation	**Name**	**Position**	**Field**
Both Rounds	Phillip Brandt	Professor	Social Science
Both Rounds	Donny Kerabatsos	Postdoctoral Fellow	STEM
Both Rounds	Jeffrey Züppe	Assistant Professor*	STEM
Both Rounds	Maude Lebowski	Associate Professor	Social Science
Both Rounds	Walter Sobchak[+]	Professor	STEM
Non-Participants	Uli Kunkel[+]	Associate Professor	STEM
	Jack Treehorn	Professor	STEM
Note: *denotes Fixed-Term faculty appointment, +denotes person is not based at BSU			

Background of the Group

The team from Case Three came together because several of the members had worked with someone named Dr. Reid Lapin from Bridgetown State. Although he is not part of the team in Case Three, one of my participants said, "you can see the node in this collaboration is Reid Lapin because he's been working with Phillip, he worked with Jack, and worked with Jeff." Through their work with Dr. Lapin, Dr. Phillip Brandt, Dr. Jeffrey Züppe, Dr. Jack Treehorn, and Dr. Donny Kerabatsos all knew each other. Dr. Züppe had an idea for a study about two to three years ago and assembled the aforementioned team to submit a grant to NSF. Dr. Züppe

realized they needed an expert in a particular field of social science on the team who had already worked in the country where the study takes place. Through a search of the BSU website, he found Dr. Maude Lebowski who has had years of experience in the study country. He contacted her and she agreed to join the group. The team applied for the NFA's 2013 deadline but was disappointed to learn their proposal had been rejected. Reviewers suggested they expand to include someone from a STEM field they had not previously incorporated. The team agreed to re-submit because they were not only interested in the work but find it important for the wellbeing of the location where the study will take place. Dr. Uli Kunkel suggested the team recruit Dr. Walter Sobchak with whom Kunkel had worked many years earlier. The team reviewed Dr. Sobchak's work and invited him. Similarly, Dr. Sobchak reviewed the team's prior proposal and their individual curricula vitae and agreed to participate in the work. Shortly before the proposal was due, the team (except Dr. Sobchak who had prior commitments) traveled to the study country to become familiar with the region; to that point, many of the researchers had not yet been to the study location. The team spent about a week together working on the final version of the grant. They met the NFA submission deadline and will learn in mid-2014 whether or not their second attempt at the grant will be successful.

External Attention

The funding agency (NFA) influenced Case Three through its proposal reviewers who suggested the team incorporate an additional STEM expert. Doing so changed the composition of the team and introduced another discipline about which others would have to learn. The addition should also make the research more comprehensive and ultimately should enhance the validity of what the group is trying to achieve. Overall, everyone reported being pleased with the new proposal and the additional elements Dr. Sobchak was able to incorporate.

Systemic Implementation

   The MFIRC's five systemic implementation sub-factors each influenced this group's experiences. In the sections that follow, I describe what participants had to say about each of the sub-factors.

   Assessing and supporting faculty work. The team from Case Three includes tenure track and fixed-term faculty from STEM, tenure track social sciences faculty, and a STEM postdoc. I asked participants how their work is rewarded in their home department. Everyone I interviewed from the group reported a different way of being evaluated so I will describe each of those then discuss the implications for the group as a whole.

   Tenure track faculty evaluation in STEM. Although Dr. Sobchak, a full professor, is not appointed at BSU, his response to my question about how interdisciplinary work is perceived and how research is rewarded was similar to others' from BSU with whom I spoke, "for research, as long as you're involved in projects that bring money to the university the university is happy." He said his department does not perceive or reward interdisciplinary versus solo work differently.

   Tenure track faculty evaluation in social sciences. Dr. Brandt is a full professor and has a joint appointment at BSU in a social sciences area as well as an outside agency with home he does consulting work. He has years of experience with interdisciplinary work because the nature of his particular branch of social science is highly integrative.

> I think what's rewarded is not interdisciplinary versus not interdisciplinary. What's rewarded is productivity. So publish a lot of papers, generate a lot of grants, support a lot of students, be successful in those endeavors, do a good job teaching, do committee work, be a leader when you can; that stuff gets rewarded. So, it is very much about productivity and in no small amount, grants.

Dr. Lebowski feels a similar pressure to get grants despite being in a different area of social sciences than Dr. Brandt. Dr. Lebowski is an associate professor and plans to go up for tenure

when she finishes a book she has been working on. Dr. Lebowski echoed the sentiments of Dr. Brandt who said the College of Social Sciences expects people to bring in research dollars. In Dr. Lebowski's area, she said the message is, "go find STEM friends" because with STEM friends come STEM-level grants and they are generally much larger than what is usually awarded to social scientists. The largest grant Dr. Lebowski has received was under $100,000. Should the Case Three group be awarded the NFA grant, she will be listed as a PI on a project worth over $2 million which would be a real coup in her branch of social science. When I asked her how her department views individually investigated versus collaborative work, said ultimately it was grant getting that was most important, "It didn't matter how much I publish – if I didn't get grants, I'd be out of luck. That was drilled into me from when I first set foot on campus." Dr. Lebowski went on to say how she strategically manages grant-getting and publishing to position herself well for RPT review:

> My understanding of the criteria for tenure and promotion has been that grant getting is extremely important, highly valued, and that you're dead in the water without it. So, recognizing that the external reviewers might have that as their main criteria I've been mindful of publishing the kinds of things and in the kinds of places an external [social scientist] from another department who would be reviewing my file would think were important and impressive.

Dr. Lebowski expressed some frustration with BSU because she thinks the institution does not take into account the amount of time grant writing and writing for publication takes, The "university says, 'apply for grants, apply for grants, apply for grants' but doing the research and publishing takes time. The problem is if you get on a grant, it takes a long time to actually do [the work]."

Fixed-term faculty evaluation in STEM. Fixed-term faculty have criteria against which they are evaluated for reappointment and promotion at Bridgetown State. Dr. Züppe is jointly appointed at BSU and with an outside agency for whom he does research. When he negotiated

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his most recent contract at BSU, his chair told him what he wanted to see from Dr. Züppe and one of the expectations is that Züppe engage in interdisciplinary work. Dr. Züppe has a history of successful collaborations and the department wishes to see him continue similar work while he is appointed there. When he explained his responsibilities to me, he distinguished between his chair's perception and the actual criteria against which he will be measured:

> I think to the degree that I publish in those areas [that first attracted attention of the department], I'll be viewed positively by my chair but I don't think I have to do that to achieve promotion. I think that the promotion is based on my productivity and my productivity is almost exclusively linked to my ability to continue to find funding and also to write publications.

Not only does Dr. Züppe need to focus on obtaining funding, he must also focus on publishing frequently. To be considered *excellent* for reappointment and promotion purposes, he must publish five first or second authored publications per year. The minimum for his appointment type is two first or second authored publications per year. The pressure is on for Dr. Züppe to work interdisciplinarily, get external funding, and publish prolifically. He had considered going up for promotion during the department's prior round of RPT review but decided against it because he did not feel ready in terms of his publication record nor did he think he had enough time to prepare adequately to submit the packet.

Postdoc evaluation in STEM. Dr. Donny Kerabatsos is appointed as a postdoc whose focus is research. As such, his "primary evaluation is [if he is] successful in getting grant funding." Interestingly, although Dr. Kerabatsos is considered a co-PI on Case Three's grant, he is not officially listed on the proposal that way because (a) the NFA has a PI limit and (b) there were two people from the same field (Kerabatsos and Treehorn) on the project so the group used Dr. Jack Treehorn's name because he is a tenured professor, a senior researcher, and has a record of success which will reassure reviewers more than if one of the main PIs was a new postdoc. I asked Dr. Kerabatsos about his not being included officially on the grant. He was unconcerned

and knew it was a good decision for the team: Treehorn has name recognition. Kerabatsos does not.

Summary of assessing and supporting faculty work. Regardless of their different appointment types, the common thread between Case Three participants is their institutions rely on academic staff to generate funds. As such, faculty and postdocs face constant pressure to do so and, according to Dr. Lebowski, the grant writing may compromise one's ability to attend to the research.

Organizational values and identity. I wondered about the division between STEM and social scientists on this team during Dr. Kerabatsos' interview. I heard Dr. Kerabatsos say, several times, "the social people" or "the social part" in reference to Drs. Brandt and Lebowski, the social scientists on the team. Grouping two very different fields together under the umbrella "social," not even "social science," made me question how seriously he took their work and prompted me to look at Case Three transcripts for similar language. When I searched for a pattern of what I considered to be dismissive language, I did not find one. As I reviewed Dr. Kerabatsos' transcript, he demonstrated his understanding of social science models, "well *model* to a social scientist means something very different – a model is essentially a mental construct or a theoretical construct for interpreting interactions." Further, of all Case Three participants, Dr. Kerabatsos gave the clearest explanation of the critical role the social scientists play on this team. He described an important, expensive study that had taken place many years earlier where STEM researchers attempted to explain a certain phenomenon but they did not include social scientists who would have easily identified a major flaw in the model: the researchers had not factored in people or how and why they make decisions. As such, the entire study and its findings are in

question. The team in Case Three wanted to avoid a similar situation so included two social scientists in the group:

> A lot of times these types of collaborations involve [STEM disciplines] and they leave out anything that's on the social sciences because it's really hard to predict what people are going to do. But when we review past efforts at trying to make predictions, we find the biggest source of uncertainty, [behavior-related social science], is also the one that was most naively approached within these collaborations that lack people with social background. Sometimes those earlier works weren't even asking the right questions about what people would do (Dr. Kerabatsos).

So, despite his casual references to "social people" and "the social" component of the project, Dr. Kerabatsos indeed takes the work of the social scientists on his team quite seriously. Further, evidence across remaining Case Three transcripts supported Dr. Kerabatsos' sentiment that the social scientists are integral to the team's work. As such, my initial concerns about a division between STEM and social science people on the team were unfounded.

Professional development opportunities. When asked what they had learned as a result of being involved with this team, respondents from STEM discussed their newfound understanding of social science methods. Three participants, Drs. Züppe, Kerabatsos, and Sobchak all mentioned their increased understanding of how social scientists approach research and especially the differences between social science and STEM models. The team also learned a lot about the history and culture of the study regions and how those elements are important and will influence the work the team does. Dr. Brandt, although a social scientist himself, said he learned a lot about Dr. Lebowski's field and how experts in her area approach their work. Dr. Brandt also said he benefits from the "good professional habits" his colleagues on the team and watching how they manage their work, said he hopes "that can rub off on me. Some of the people are very organized. I'm not."

Professional networking opportunities. The person (Dr. Reid Lapin) who brought Drs. Treehorn, Kunkel, Kerabatsos, Brandt, and Züppe together is not actually on the research team in

Case Three. Drs. Treehorn, Kunkel, Kerabatsos, Brandt, and Züppe met each other when they

worked with Dr. Lapin at some point over the years. Dr. Kunkel had worked with Dr. Sobchak at

one time and recommended he be included on the grant. Dr. Züppe reached out to Dr. Lebowski

based on a search of the BSU website for faculty on campus who worked in the study region and

had her set of skills. As Dr. Kerabatsos said, Dr. Lapin was the "node" in the genesis of the

group and through the network expansion that took place by working with him, several of Case

Three's members were able to create a new group to initiate this project.

Until recently in his almost 30-year career, Dr. Sobchak has not been involved with

interdisciplinary work. He said he spent nearly 20 years at another institution and "I don't think I

ever talked with someone from a different department." He said people were focused on their

own research and collaboration was not actively encouraged. He was surprised when he switched

institutions and found interdisciplinary work was encouraged. He was further surprised when he

found himself diving into research with people from fields he had never imagined working with.

Doing so has been satisfying and has also expanded his professional network:

> "I've found that fascinating to collaborate with others. In my own case it's actually
> helped me because I found more channels to do research than my original research
> involving <redacted> and <redacted>. Now actually it's expanded my view and my
> research into many other areas.

I asked Dr. Lebowski about working with the Case Three team and how it has influenced

her professional network. She said her department is happy because, as stated earlier, they

wanted her to "find STEM friends" and being part of this team is a promising development in

terms of potential funding. I wondered what, aside from the pressure to find STEM collaborators,

convinced her to accept Dr. Züppe's invitation to work with the team:

> He has a lot of experience there [study location] so it was easy to conceptualize working
> with him but also, inevitably, if I'm going to engage in interdisciplinary research with
> STEM friends, they're not going to be my friends when we start. You get sucked in
> [laughed] or you get connected and all kinds of new connections might open up through

that. But I've been doing research on my own almost exclusively so I don't have the networks that work that way for me.

Dr. Lebowski was working on a book when Dr. Züppe contacted her so the timing of the invitation was not ideal but the opportunity itself was perfect so she decided to go for it. She feels good about the group's second proposal and says it is a much stronger application than their first one.

Communication and information technology. The group from Case Three communicates most often via email because they are geographically dispersed across campus and also have members in two other states. The final major writing and editing spurts happened while most of the group was traveling in the study location. They took advantage of being sequestered in a remote location to sit together, have everyone in the document, and do real-time editing using Google Drive. Several of the participants mentioned that last writing spree while they were away together and mentioned how helpful Google Drive is for that type of group writing application.

Factors Outside of MFIRC

During analysis, a number of themes emerged from the interviews that were not specifically accounted for within the MFIRC. The following section discusses each of those as I have labeled them: administration, disciplinary boundaries, funding and resources, leadership, organizational politics, and place.

Administration. Dr. Züppe's responses to various questions led me to include this category under additional factors. He is the lead PI on the grant the team just submitted and was also the lead on the first funding attempt the group made. He said he learned a lot about "grant writing, time management, budgeting - you know, all the skills involved with managing a grant writing process. These are people [his co-PIs] who are more experienced than me at that." The

challenge of being the lead PI is managing those responsibilities and ensuring all the details have

been attended to. One of the benefits is the additional funding the lead PI be awarded when

money flows back to the department via indirect cost credits (IDC). Dr. Züppe explained the

process of how the group decided on distribution of IDC:

> We divided it. So there are five different collaborators [officially listed on the grant] so
> we divided 100% [of the IDC] by six and gave me two portions and then everyone else
> got one portion. Essentially I got extra resources because I'm the PI and it's going to take
> me extra time and it's going to take my operating unit more administrative costs to
> administer the grant as a result. So, we came up with a relatively democratic process for
> that.

Disciplinary boundaries: This team was clear about the challenge of learning each

other's disciplinary language although they did not describe the experience in negative terms.

Rather, they discussed language learning as an integral, interesting, sometimes shocking, and

ongoing process within the development of both the team and the project. Dr. Brandt suggested

one of his main roles was to act as "translator" for his and Dr. Lebowski's work. The rest of the

team had never worked with people in Dr. Lebowski's field before, but Dr. Brandt himself had

been involved in multiple interdisciplinary groups and tried to preempt comprehension problems

by working to provide explanations. "One of the things you'll find if you want to do

interdisciplinary work is you have to invest in understanding how they think and what their

language is. They have to invest in you and you have to invest in them. That makes successful

teams" (Dr. Brandt).

My interview with Dr. Kerabatsos, the postdoc on the team, provided insight into some of

what the group learned about each other's disciplines. He recalled being shocked at some

publication realities in social sciences, "So in <Lebowski's field>, for instance, if you want to

publish a paper it takes a year and a half. It's a terrible long time compared to what we're

<natural science> talking about so we'll sit down to a meeting and talk about the first pubs we

can get out in year one. Dr. Lebowski says we'll be talking about year two or three [before

anything could hit publication in that field's journals]. So the pace is different."

Place. Most of the members of Case Three traveled to the study region together just

before their 2014 NFA proposal was due. The trip afforded them the opportunity to get to know

each other on a more personal level and also spend time immersed in project discussions without

the distractions of everyday life at home. Although several people mentioned something about

the group's trip, Dr. Lebowski's response included all the elements about what made traveling

together so important:

> Everyone we met with we presented the project to. I began and I'm thinking other people
> did as well, to understand better what the different pieces were and how they could fit
> together. So, we were meeting with people during the day and then at night working on
> the proposal and talking with each other about what our hypotheses will be, what we will
> need to look at to do this. I came away from that trip with a much better sense of how the
> pieces were going to fit together and to some degree, reshaped my understanding of my
> piece so it would work better with the other pieces. I think we came away from that
> feeling more like a team although I think they [her co-PIs minus Dr. Sobchak] went into
> it already very much a team.

Dr. Sobchak did not join the group on the trip because he had prior commitments. He did

not seem bothered by a missed opportunity for bonding and, in fact, has had a number of

experiences where he has collaborated with people he has only ever known through the Internet.

Before committing to the project with the team from Case Three, Dr. Sobchak researched the

members and when he was satisfied the group was skilled and that he would find the work

interesting, he felt comfortable signing on.

Case Three Round Two: Muddling Through

Dr. Züppe offered the following about muddling:

> I think the muddling through is really informative and important especially if it's a team
> that ends up forming a long-term collaboration. You probably muddle through at the
> beginning but I feel like a lot of it has to do with the people on the team. Like, if there's a
> highly specialized team that doesn't think outside their disciplinary boundaries, then I
> think it makes it inherently more prone to muddling. A lot of the muddling related, I

think, to communication issues, academic culture, different expectations for how grants get written, and personalities. Academics are inherently intense group of people and we're a lot of Type A personalities out there. I think in the specific case of my collaboration with the group that we talked about so far, I think we haven't muddled barely at all and I think that's because everyone's already been doing interdisciplinary work and it's a team that was assembled, you know, parts of which were assembled before I even got there. I think everyone came because of their academic interests everyone was prepared productively without a lot of muddling. I think also because of the legacy of prior work together, the team that we formed, because there's a core of us – four of us [Treehorn, Züppe, Kerabatsos, Brandt] who were already working together that was already kind of dealt with and I never had to see that.

Dr. Züppe had interdisciplinary experience in graduate school and said, "ya, I think that's fair to say I was trained [to do interdisciplinary work]." He went on to say that when one becomes a PI is not the time to get training – by then, it is too late:

I don't feel like the time to train is after you formed a collaboration. I think if training can be beneficial, it's in the grad school phase of education, before primary investigators are formed – before someone has achieved a status where they could be a primary investigator. I think that's when this practice has to be done. Once you're in a faculty position, your time is so dissected and it's so – you know, you're essentially always at a time-deficit. For that reason you can maybe clip out a little bit of time here and there for a workshop or something but I feel like you kind of either have it or you don't. I think the raining needs to happen earlier not by the time you've already formed a collaborative team.

Dr. Lebowski also suggested people could benefit from training and although she did not pinpoint a window of opportunity the way Dr. Züppe did, her response suggests graduate school is a good time to guide students into interdisciplinarity:

I'm affiliated with the <program> run through <center> and I've got, in my seminar in <Lebowski's field>, students in that program so I get people from <redacted programs> in that course. They engage in interesting conversations with social science students and some of my students have participated in that program and I think it's helped them to understand the conversations going on in the more natural science departments that are represented, disciplines that are represented there as well. I think I'm all for that and I received none of that in my training. So hopefully they'll be muddling through less than me.

Dr. Kerabatsos has been working with Dr. Treehorn for many years, since he was an undergraduate student. Because Treehorn's lab tends to do interdisciplinary projects, Dr.

Kerabatsos is familiar with how to work across areas because he spent his formative time in higher education engaged in interdisciplinary projects. Not surprisingly, Dr. Kerabatsos' view of training is "you're going to need some type of apprenticeship in this thing – no amount of training can make you an expert in working with people in other disciplines." Dr. Sobchak's thoughts on training for interdisciplinary work, after a long successful career, are as follows: "At this point I don't think I need much or any – you learn on the job. After you finish your PhD you have expertise in one particular area maybe because of your dissertation but you start other research and get involved in these other things and you learn what you need to learn along the way. That's my philosophy." Like his colleagues, he suggested learning by doing is effective then also said, "I don't think you can really train. It's a very good question because I don't think there's going to be education that will actually train you for interdisciplinarity or collaboration. I don't think we teach students how to collaborate – that's my own opinion."

Networks

Most of the participants from Case Three are willing to branch out and work with whom they are unfamiliar. Dr. Brandt was an exception and said, "I'm old enough and in a position of tenure where I can pick who I work with. I wouldn't participate [if he did not know and enjoy working with the people] it's just too much of a personal investment. I have many other projects I can work on." Unlike Dr. Brandt, Dr. Züppe is quite willing to work with people he is not familiar with and added two relatively unknown members to the Case Three team. Dr. Züppe recruited Dr. Lebowski for the Case Three team after reading about her work on the BSU website and also extended an invitation to Dr. Sobchak after Dr. Kunkel recommended him. Dr. Sobchak joined Case Three without having met anyone on the team except Dr. Uli Kunkel and Dr. Lebowski also agreed to participate having not met the others. Although Dr. Kerabatsos was well integrated into the Case Three team because he has been working with Dr. Treehorn and

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most of the collaborators for several years, he has a side project with other colleagues and when I interviewed him, they had just made the decision to bring on someone who none of the team had ever met.

Dr. Züppe's recruited Dr. Lebowski by reading about her then connecting with her to discuss the project. I asked what makes him different from other people who might not be willing to cold call someone.

I feel comfortable doing that because I have a need - I have a specific need and if there's no one in my immediate network to fill that need, I'm motivated to implement the vision that I see, as I see it. So if I recognize a need for a certain skill set then I will try to secure that skill set from my local network first, my extended network and then, if I still haven't found someone I'll call people out of the blue or email and set up a call – I've done that on several occasions. So I don't know what separates someone else from me but in my case, I'm interested in making the project happen the way I see it. I'll do my best to hit that mark and if I can't then I'll start making concessions.

I also asked Dr. Lebowski about how she would go about finding people, especially if the Case Three people had not found her first. She said she would turn to "the centers on campus that have either been developed to do this or have taken on that task" or would connect with people she has met throughout the university over her time at BSU.

Integration

Dr. Kerabatsos' response to questions about integrating project pieces did a great job of explaining how some of the integration happens but also when and why some parts are naturally separate:

> Generally a method is a disciplinary one. People talk about transdisciplinarity and the migration away from disciplinary structures within a university. Frankly, it's a difficult thing to do because our methods are so very different that you would have to move away

from that – you'd have people that don't speak the same language and that's derived from their methodology. I'll never be able to poll <redacted> with a survey and get answers I need just like they could never go out with GIS and measure the people with remote sensing and satellites. We have fundamentally different methods so naturally anything that's methodologically focused will have its own division of work, right? And the task itself, at least the way we chose to structure this [research project], this one has fairly separate social and natural sciences tasks and that will get integrated in a third task.

The struggle Dr. Lebowski had the first time the team applied for the grant was she was not entirely clear how the social science pieces fit together nor with the rest of the larger project. For the second grant, the team spent a lot of time talking about integration, especially while they were away together in the study location, and the result is a more coherent, more robust project:

All the models they're trying to put together – all of the physical models – that in itself is a really really interesting endeavor. And then linking that as they intend to do with the [social science part] across time it is exciting to me. I feel like already there's something that's bigger than the sum of its parts. So it's not just me thinking <redacted> it's Phillip as well – he's focused on the <redacted> but he's able to put it in a larger, sort of, policy context. So I feel like our conversations have already generated something that was more interesting than Phillip's piece and my piece (Dr. Lebowski).

Like Dr. Lebowski, Dr. Züppe is happy with this year's grant, which, he said,

demonstrates the potential to result in something meaningful:

I think I can already recognize the opportunity for some mergence – mergence being, sort of, something greater than the parts. I recognize that already and I think that, in our case, we're probably closer to the pie but I also see the ingredients – I think there'll be some solid disciplinary advances made but I see a lot of potential for mergence in this project. There's also another dimension which is the potential to help society in the application and that's really a lot of my focus.

CHAPTER FIVE: MULTI-CASE ANALYSIS

This section provides a synthesis of findings across cases and is organized around themes that emerged across cases. I present findings in chronological order (i.e., I share themes from round one before describing round two), which has the effect of expanding the discussion from a narrow focus on the MFIRC to broader issues around interdisciplinary collaboration. The chapter begins with a discussion of discrete categories that emerged within systemic implementation sub-factors and then summarizes how well the first round of interviews addressed the research question: How well does the MFIRC describe the experiences of people working on combined STEM/social science interdisciplinary research teams? Next, I report on the three main themes I discussed with participants during the second round of interviews: professional networks, muddling through, and integration. I conclude the chapter by summarizing the extent to which I was able to answer the research question.

Discrete Categories Within Systemic Implementation Sub-Factors

As anticipated, external attention and systemic implementation along with its sub-factors, all emerged as factors influencing the groups in my study. This section to explores emergent themes and reflect on the extent to which the data addressed my research question. I end the section with a discussion of the state of the research question and prepare for Chapter Six where I consider my findings in terms of the broader literature as well address the implications and imitations of this study.

Assessing and supporting faculty work. When reporting the findings for Cases Two and Three I discussed the sub-factor Assessing and Supporting Faculty Work by breaking it into categories. In Case Two, the social science doctoral students on the team faced similar productivity pressures to those of their faculty counterparts; they were responsible to present and publish and were, in turn, ranked and awarded funding based on their output. People from

various academic ranks comprised the Case Three team, each of which I reported on in a preceding section. Although the reappointment and promotion requirements and appointment categories for everyone in that group are different, the common thread is they are expected to bring grant money, as much as possible, into the institution. The next most important task for the members of Case Three is to publish: again, as much as possible. The main PIs in Case One are both cross departmentally appointed at BSU and, like their colleagues from Cases Two and Three, also face pressure to get grants and publish frequently.

Although I mostly heard from participants about the ways they are evaluated or face pressure in their jobs, two things emerged that appear to facilitate interdisciplinary collaboration: departmental authorship policy and institutional structures. One department on campus, where Drs. Webb and Gunadi hold an appointment, has an authorship policy to protect graduate students. The policy counts papers written by graduate students toward the faculty members' RPT requirements to ensure (a) graduate students are given ample opportunity to take the lead in writing for publication and (b) faculty members are not unduly penalized for allowing/encouraging their graduate students to be first author. No other participants discussed similar policies in their own departments. Dr. Kerabatsos did mention the importance of sharing authorship credit with students and expressed frustration that not all faculty members at BSU do so. He did not, however, indicate a formal policy existed and it seems authorship decisions are at the discretion of PIs.

Bridgetown State has numerous interdisciplinary centers and programs, some of which were mentioned by participants during round one of my interviews. Several of the faculty I interviewed met others through centers or approached centers for help or advice during the initial stages of their projects. Dr. Webb said, "we met Morgan Davis through inquiries about this

project and looking for funding for it within the university so the university's structure really helped facilitate the project." Similarly, Dr. Lebowski said she consulted with interdisciplinary centers on campus for prior projects. Dr. Lebowski herself was located for Case Three's project by Dr. Züppe who found her through BSU's researcher database. Bridgetown State has staff dedicated to science writing who do press releases and work to translate what is happening at BSU into information for the university community and beyond. By publicizing research at BSU to others within the institution, and having a searchable experts database, experts are able to find each other on campus.

Communication and information technology. The unexpected finding here is how participants, across all three cases, referred to *language learning* and *translation* when discussing how disciplinary boundaries influenced their communication. Many participants viewed other disciplines as "foreign" to the extent that interactions would require language acquisition skills. When reporting findings, I used the sub-title *disciplinary boundaries influencing communication* but given the foundational nature of language as a tool for communication, I determined something so important does not belong as a sub-factor of a sub-factor within a model of many factors intended to represent interdisciplinary research collaborations.

Place as a sub-category of organizational values and identity. Two of the three groups in this study have teams that are geographically dispersed but members traveled internationally together. The other group does not travel together but has offices along the same hallway as each other. Participants who traveled internationally with their colleagues discussed the importance of the trips in terms of their influence on group bonding, idea generation, increased momentum and enthusiasm, and ensuring people had at least a cursory understanding of the region and the people in the study location. Dr. Kerabatsos said there is an adage in his field, "don't model a

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system you've never seen" because, he said, "you'll make a naïve mistake." Given all three teams are trying to model something as part of their research, trips to the study location for Case groups One and Three were crucial to get "everyone on the same page" (Dr. Brandt). Further, sustained proximity to each other facilitated people getting to know each other both as colleagues and in more informal ways. Everyone who traveled remarked on the benefits of the trips. Dr. Lebowski discussed the significant difference she perceived from 2013 to 2014's funding proposal and she attributed some of the strength of the latest incarnation to the group having traveled together and having been forced to repeat, time and again, the goals of the research and how all of the pieces fit together. The team did not visit the study site before writing the 2013 proposal; only two of the group members did research there and one other went to the country but was there on holiday.

Similarly, members of Case Two discussed the importance of their being located so close to each other. Laurie said the STEM people would often send an email announcing they would be doing a particular experiment that afternoon and anyone who wanted to watch was welcomed to attend. She found that helpful because it helped her not only understand the methods but also helped her see, first hand, the phenomenon the group was attempting to model. Similarly, Mike said being near each other allowed him to pop down the hall and "hang out" with the STEM students where they could "bounce around ideas." Laurie mentioned that re-locating Dr. Simms's graduate student to the group's hallway has increased the ease of their communication and she perceived it has increased the student's satisfaction with the work. Dr. Simms's student did not participate in this study so I was not able to confirm Laurie's statement about her colleague's increased job satisfaction.

I did not anticipate physical togetherness would be a theme in my study mostly because I did not consider that I would find groups where members spent extended amounts of time working next to or traveling with each other. Although technology can facilitate communication between group members, and indeed Dr. Sobchak has had several successful collaborations with people he has never physically met, for the majority of people in my study, being in the same place together, either consistently over time or for a short time but completely immersed, seems to have been an important and supportive factor in the group's work.

State of the Research at the Conclusion of Round One

The research question guiding this study was how well does the MFIRC fit to describe the experiences of interdisciplinary STEM/social science research groups? The model on which the MFIRC was based, Rhoten's (2004) model, was conceived after studying NSF-funded interdisciplinary centers. The MFRIC came from further study of an NSF-funded science and technology center and so I worked to determine if the model would describe research groups that included social scientists. After analyzing the data from round one, I could see the MFIRC had done a satisfactory job of categorizing some of the factors influencing the experiences of the research groups in my study. In some cases (i.e., Case One, Case Three), the model missed factors altogether (e.g., administration). In all cases the model over-stated the influence of intrinsic motivation, did not account for physical togetherness of groups, nor was it detailed enough to illustrate the influence of disciplinary boundaries on communication. Although the model was on the right track, so to speak, it would not be an ideal way to represent the experiences of the research groups in my study.

As I considered the model, and thought about how it might best be configured or whether a model could or should account for all eventualities, several questions came to mind regarding some of the bigger picture issues raised in the literature and also from my interviews. First, is

there was a way to prepare people in advance for challenges they may face during interdisciplinary work (e.g., language barriers, administrative surprises)? Second, given the importance of interdisciplinary work in addressing some of our most pressing and complex problems, how appropriate is relying on chance (e.g., Case Two members being co-located along the same hallway), or who people happen to know, to bring interdisciplinary groups together? As such, I focused on people's networks, how they find collaborators, and understanding if that phenomenon was something that could be represented within the MFIRC. Finally, I questioned how groups were integrating their work to make it truly multi-disciplinary and greater than the sum of its parts. Given the pressures faculty are under to publish, thinking members may branch off and write disciplinary pieces relevant to their own field is natural. There were several instances where people discussed "divvying up" work (Mike Myers) along disciplinary lines and that disciplinary experts would take the lead on writing those papers. What was less clear is how the groups intended to create more holistic output that would include the work of all members across disciplines.

Muddling Through

Participants were somewhat mixed about the effectiveness of training to prepare for interdisciplinary work. For the PIs, the drag of administrative responsibilities was somewhat unexpected so preparing for that might have made their experience slightly less stressful. For the other participants, language learning seemed to be the major hurdle and most everyone agreed that the only way to break through disciplinary language barriers was actually to engage in the work and "figure it out as you go" (Laurie Stroud, Case Two). Most participants were clear that interdisciplinary skills can only be learned by doing and any sort of training would basically be preparation to tell people what they may face (e.g., you may face administrative snags, you will need to learn another discipline's language). The graduate students were happy to be learning

interdisciplinary skills during their graduate training and indeed, at least three PIs said graduate school is the time to get interdisciplinary exposure. Dr. Züppe (Case Three) went as far as saying waiting until one is already a faculty member was "too late" to start working interdisciplinarily because the start-up costs of learning everything necessary to do the work well, are too high. He suggested new faculty do not have time to spend learning interdisciplinary skills when grant getting and publishing are high priorities and most faculty are already "facing a time deficit." Some participants also mentioned the value of understanding how to get along with others and be engaged and interested in others' work. Some were skeptical that a program could "train people to be interested" in someone else's work; you are either inclined to do so or not (Laurie Stroud, Case Two).

Several participants also placed value on muddling because they found it instructive in terms of learning how colleagues thought, how different disciplines approach problems, and in terms of generating ideas. Mike (Case Two) found muddling helpful and so did his PI Dr. Wynn who said he wants his people to "just do the damn thing and see what we get." As long as ambiguity and challenge led to a productive end, people seemed pleased and were confident the struggle had actually made the final result better. As such, participants were not keen to use training, in whatever form it might take, to alleviate or minimize constructive interdisciplinary muddling.

Networks

Willingness to expand beyond one's professional network and work with strangers seems to be an individual decision. Two of the more senior researchers I interviewed had firm opinions about working with new people. Dr. Brandt (Case Three) is at a point in his career where he is not interested in spending time or energy working with people he is unfamiliar with or have not at least been vetted by someone he trusts. Similarly, Dr. Wynn is not interested in working with

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anyone he is not more senior to and where he cannot "be in control." Both are at a stage where they can make choices about whom to work with. The newer faculty members have not reached this phase yet and are driven, in part, by intense expectations to get large grants and publish.

Dr. Züppe, Mike Myers, and Dr. Sobchak all discussed finding people to work with based on searching the literature and reaching out to a particular author they admired. They did not hesitate to do so and did not have much to say about the interpersonal dynamics of working with strangers. Dr. Züppe's focus was on the work and executing his "vision" for the project "as I see it." Others (e.g., the graduate students on Case One, Dr. Gunadi) said they would first turn to their networks to find potential collaborators because working with someone they know, or someone with whom they have a mutual trusted contact gives them a better opportunity to learn about the person's interpersonal skills and work habits. The people from Case One have been through a frustrating situation with two of the co-PIs on that project so I imagine part of their reticence to work with strangers is influenced by how things have unfolded with Drs. Smith and Davis.

Integration

Each of the projects being undertaken by groups in my study are multi-year studies supported by national funding agencies for one or more million dollars. Each group is in a different phase of the work and none, as yet, has published any of the large, integrative papers they have planned for when all data is collected and analyzed. I wondered how the groups intended to bring together the work of the multiple disciplines represented on their teams especially given the many references to dividing tasks down disciplinary lines.

What emerged from the interviews was a sentiment that people are disciplinary experts, that expertise in a particular area is a good thing, and that a combination of disciplinary-based and synthesis type work is necessary within each project. Laurie Stroud (Case Two) said it nicely

when she explained she has no time or desire to learn everything that the STEM group on her team is doing but she does want to understand it to the fullest extent possible. Participants also said that separation of disciplines on an interdisciplinary project was not necessarily a bad thing nor did it signal a lack of integration. Rather, disciplinary experts are "experts in a particular method" and "you want that" because the expertise is what you need; if everyone was trained interdisciplinarily, no one would be an expert and everyone could only know a little about a lot of things, which would weaken the research and you could never actually address a problem with the depth it requires (Dr. Kerabatsos). Each of the groups has synthesis planned for later stages of their projects. Case Two will submit the experiments (STEM) and the analysis (social science) to their co-PI (STEM) who will create a model using everything the STEM and social science members have generated. Similarly, the teams from Cases One and Three will incorporate social science elements into natural science models to, they hope, predict phenomena over time. Until each of the component parts has been completed, synthesis cannot take place but all groups have that larger integration planned. Further, the groups plan to work on integration as a team; none of the participants reported that one person, in the end, will write a final paper simply outlining the findings from STEM and social science components of the project. The teams all plan to work together on synthesis although it may be the main PI who is responsible for actually pulling together the pieces and administering the writing process.

State of the Research at the End of Data Collection

Rhoten's (2004) model initially was created to illustrate how interdisciplinary teams are supported, or are not, and by which entities (i.e., external attention, intrinsic motivation, systemic implementation). Perry et al. (2012) expanded the model by adding discrete sub-factors within systemic implementation that might help explain where attention can be focused to support collaborative groups. After round one of this study, I could see that the MFIRC did a satisfactory

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job of representing some factors that influence interdisciplinary groups but that it lacked or over-emphasized certain elements. I also considered some of the larger issues in the literature for example, how groups come together, how work gets integrated, and how teams can avoid pitfalls. As such, in round two interviews, I focused on some of the broader issues groups had mentioned in round one and less on the discrete MFIRC factors.

By the end of round two, I can see that external attention (i.e., external funding) is linked closely with assessing and supporting faculty work (a systemic implementation sub-factor) and that together, those two are more representative of what seems to be motivating researchers than the original *intrinsic motivation* label on the MFIRC. How groups are formed also factors into the work and is somewhat influenced by funding policy as well as how faculty are evaluated. The following is how I imagine a researcher's thought process might go based on what participants told me about how groups, both presently and in the past, have come together:

> I need a grant. The grant should be as large as possible. STEM grants are large! Who do I know in STEM? What do we all study? Is there an agency funding that? When is the RFP due? I should call persons A, B, and C right away. Who else do we need to meet the criteria for this RFP? Oh man, we need a social scientist. I need to ask if people know anyone. Okay, person C knows person D who works in that area. I hope person D is good. I'm going to put together a meeting so we can write this thing. It's due in a month and a half.

Alternatively, participants also described having worked with a group before, enjoying their experience, and hoping to continue their line of inquiry and to do so, figuring out ways to "repackage the work" (Dr. Webb, Case One) to appeal to the same or different funders. The genesis of a group seems based on (a) the need to do the work or be fired, (b) availability of fundiig, and (c) the availability of fellow researchers.

I considered how integration of disciplines was factoring into the work people were doing and whether it could or should be represented in a model of interdisciplinary collaboration. As stated earlier, Rhoten's (2004) model and the MFIRC both appeared to presume that, if groups

were supported adequately, integration would just happen. From what emerged via participants in my cases that seems to be the case. Each of the groups is only part of the way through their work but have plans to produce models that integrate each of the disciplines. I am not sure it is necessary to try to represent integration on the model aside from ensuring that supports are in place so groups can work to their full potential.

In Chapter Six I will review the genesis of the MFIRC and suggest a different way interdisciplinary collaboration can be modeled that more accurately represents factors that influence teams, as I understand them from both the literature and the findings of my study. The next chapter will also include a discussion of the implications for my study and also its limitations.

CHAPTER SIX: DISCUSSION, IMPLICATIONS, AND LIMITATIONS

In this chapter I review the research question guiding this study and discuss the genesis of the MFIRC and the purpose it serves. I then suggest a different way interdisciplinary collaboration can be modeled, which I believe more accurately represents factors influencing research teams. Throughout, I tie my findings and model suggestions to extant literature. Finally, I discuss the implications for my research and describe the limitations of my study.

Review of the Research Question and the MFIRC

The research question guiding this study was *how well does the MFIRC fit to describe interdisciplinary research groups composed of STEM/social science members*? After several years of studying interdisciplinary research centers, Rhoten (2004) created a model to illustrate how in "the academic research environment…the transition to interdisciplinarity and consilience does not suffer from a lack of external attention at the 'top' or intrinsic motivation at the 'bottom,' but, rather, from a lack of systemic implementation in the middle'" (p. 6). The thrust of Rhoten's article was to demonstrate that researchers themselves are willing and excited to work interdisciplinarily, and funders are committed to supporting multidisciplinary projects, but higher education institutions have not embraced the movement toward interdisciplinarity. Rather, she argued, institutions "tend to approach interdisciplinarity as a trend rather than a real transition and thus to undertake their interdisciplinary efforts in a piecemeal, incoherent, catch-as-catch-can fashion rather than approaching them as comprehensive, root-and-branch reforms" (Rhoten, 2004, p. 6).

Rhoten's (2004) model informed the organizational evaluation of an NSF-funded science and technology center conducted by Farrell et al. (2011). Initially the model helped to frame the study's findings. Over time, as the evaluation project progressed, Farrell et al. (2011) found discrete elements they thought helped to explain some of the nebulous space within the systemic

implementation portion. In 2012, Perry et al. formalized Farrell et al.'s additions to the model and it is that version, the MFIRC, which I studied in this research. Although there are three main model elements, external attention, intrinsic motivation, and systemic implementation, I focused this research on systemic implementation because it is a broad, ambiguous category and it is also where Farrell et al. and Perry et al. modified the model to include discrete sub-factors.

The model was created and later modified as a result of studying science and technology centers, but I wanted to study how well the model fit to describe a research situation that is more common than a large, multi-million dollar NSF-funded center: a small research group convened by colleagues. Also, I wanted to determine how well the model fit to describe groups when social scientists were added to the mix; the MFIRC and Rhoten's (2004) original model was based on STEM disciplines and increasingly, social scientist and STEM colleagues are working together (Bastow, Dunleavy, & Tinkler, 2014)

How the MFIRC Fit

As described in Chapter Four, the MFIRC did a marginal job of fitting the data in the current study. Figure 3 provides a visualization of how data clustered on the model and which

factors emerged that had not been accounted for in the MFIRC.

Figure 3 Data Mapped to the MFIRC

Figure 3 Codes as frequency categories laid over MFIRC to illustrate data clustering.
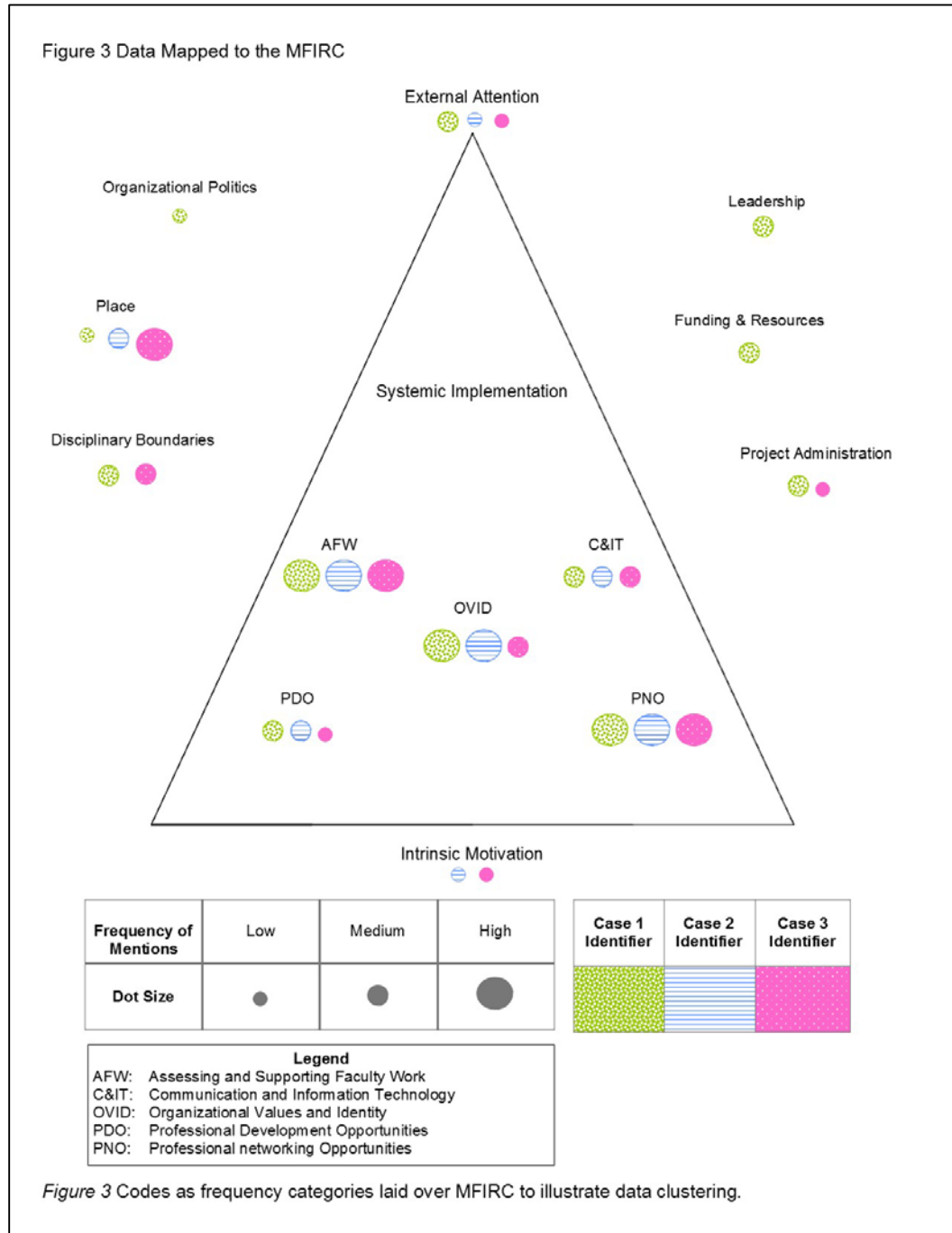
To create Figure 3, I looked at code occurrences across each case then plotted the

frequencies on a graph. Code application frequencies ranged from one to 77 and, after reviewing

the plot, I observed three natural cut points to create the categories *low, medium,* and *high.* The

frequency plot loosely resembled a normal curve with a small number of codes being recorded either rarely or very frequently (i.e., at either tail of the curve). As such, I labeled code occurrences between one and 15 *low,* codes applied between 16 and 60 times *medium*, and codes appearing between 61 and 77 times *high*. I tried several ways of understanding the findings (e.g., code cloud, charts), and laying the data over the MFIRC, as illustrated in Figure 3, was most effective in terms of visualizing findings.

Not surprisingly, data clustered around model elements about which I asked specific questions, namely the five sub-factors of systemic implementation. Intrinsic motivation received minimal attention by participants although several people, from all three groups, discussed the influence of external attention, mostly in relation to their funding agencies. As discussed in Chapter Four, participants described several new factors that I came to call *funding and resources* (at the group level), *leadership, place, organizational politics,* and *project administration* and each of those categories is represented in Figure 3.

Problems with the MFIRC

In the following sections, I describe challenges with the MFIRC and suggest a new model that incorporates my findings and provides more clarity than the MFIRC currently does.

Shape of the model. My peer debriefer suggested the shape of the MFIRC placed importance or weight on intrinsic motivation because of its position at the base of the triangle (i.e., intrinsic motivation looked like the foundational, most important element). A second peer debriefer said the triangle shape suggested hierarchy as though one begins at the bottom and can progress toward the peak like, for example, in Maslow's Hierarchy of Needs. I had not perceived the MFIRC or Rhoten's (2004) model to be hierarchical and therefore had not considered the influence on readers the shape of the model would have.

Focus of the model. As I reviewed my findings and attempted to visualize how they fit with the MFIRC, I realized the model was an ineffective mix of elements: influences on and outcomes of interdisciplinary groups. For example, an influence on interdisciplinary collaborations is how effectively group members communicate. An outcome, however, is expanded professional development opportunities. As I mapped my findings, two separate categories of elements emerged: *antecedents to/influences* on and *desired outcomes* of interdisciplinary collaboration. Based on my data, I decided the MFIRC, as it was laid out, was not representative of what brings groups together *and* what influences them *and* collaboration outcomes. In the following sections, I describe an updated Model of Factors Influencing Interdisciplinary Research Collaborations (MFIIRC), which incorporates literature and my findings to create a picture of interdisciplinarity at Bridgetown State University.

A New Model

The new configuration abandons the triangle in favor of circles – a shape that does not connote hierarchy or order of importance. The new model (Figure 4) has two sections: Antecedents/Inputs (on the left) and Potential Outcomes (on the right). Within each section are institutional/external level, group level, and individual level factors influencing interdisciplinary work. I used dotted lines on the borders of the circles to illustrate the permeability of barriers (e.g., the institutional context influences what happens in the group) and spanning each section is an arrow to illustrate that should the factors align well, desired outcomes may be achieved. Each of the factors listed in the model not only emerged with my participants but has also been discussed in the literature cited throughout this study. Delineating levels of influence was important so readers could quickly see which influences emerge from where. Similarly, parsing out how benefits affect each stakeholder (e.g., the institution, the individual) creates a clearer picture of how some of the more intangible outcomes of collaborative work might manifest.

Table 5 (Appendix D) provides a concise summary of each factor illustrated in the MFIIRC (Figure 3).

Figure 4 Model illustrates antecedents/inputs and potential outcomes of interdisciplinary research collaborations at the institutional, external, group, and individual levels.
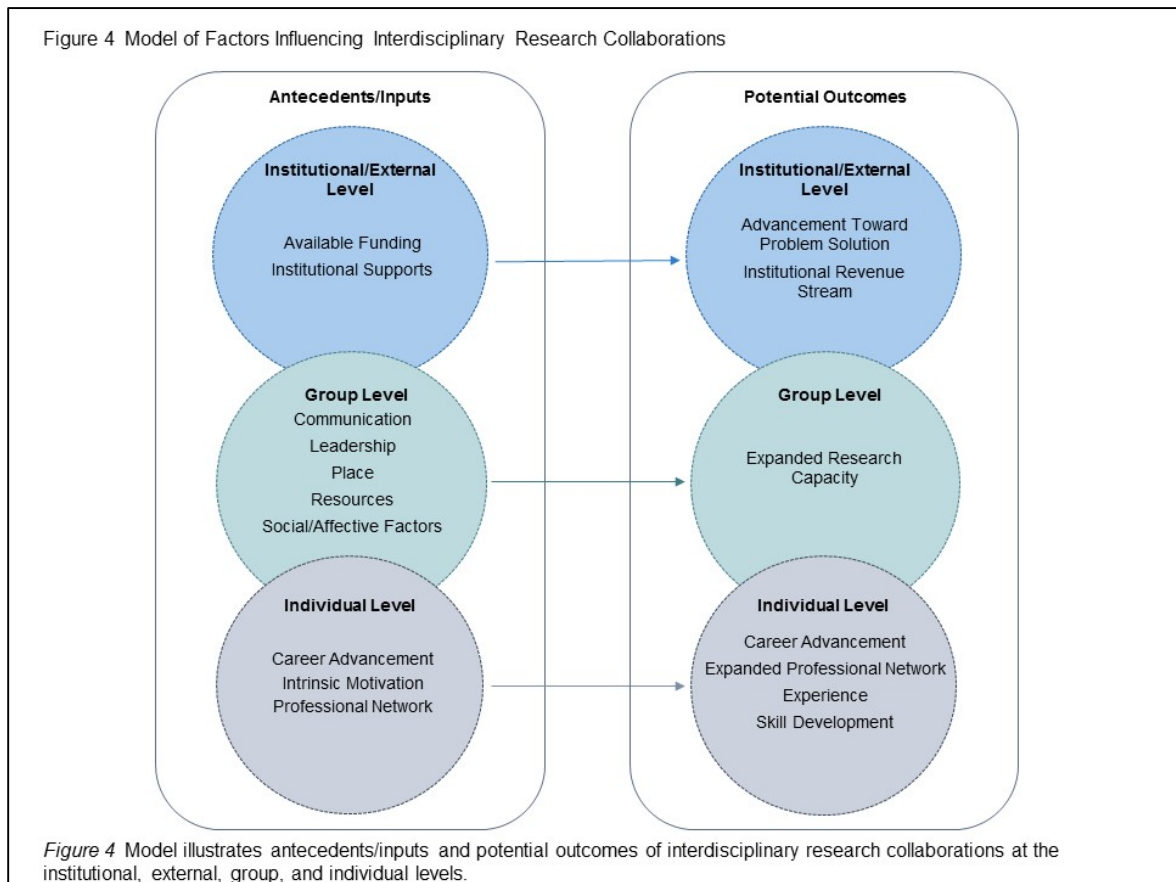
The individual level. Listed among individual level factors, on the antecedents/inputs side, are *career advancement, intrinsic motivation*, and *professional network*. As discussed in the literature and throughout this document, career advancement (e.g., RPT, graduation requirements) is a salient issue for researchers and, at least for some participants in my study, is a powerful motivator to be involved with a collaborative group. As such, career advancement is included in both the antecedent/input and potential outcomes sections of the MFIIRC. Also driving involvement in interdisciplinary research is intrinsic motivation – the general curiosity or passion people have for their field of study. Professional networks often determine who will become involved in a collaborative group and, as they work together, people who did not

previously know each might become members of each other's networks. Because it is both an influence and a potential outcome professional networks is included in both sections of the model. *Experience* working on an interdisciplinary team is valuable and can only come from participating in that sort of group. Participants mentioned their prior experience working with interdisciplinary teams when they described how they engaged with their current group; that they were familiar with collaborative processes proved helpful. Similarly, most participants suggested their interdisciplinary work facilitated *skills development* they otherwise would not have had an opportunity for. For example, they learned new analysis techniques, methodologies, and transferable skills (e.g., communication, project management).

The group level. Influences at the group level are multiple and include *communication, leadership, place, resources*, and *social/affective characteristics*. As discussed by many participants, communication, place, and social/affective characteristics (e.g., trust, competence) influenced their productivity and also their enjoyment of working on a collaborative team.

Leadership and resources (e.g., grant administration, ensuring the right mix of skills is included on the team) are factors at the group level but are often within the realm of PI responsibilities. In the current study, several participants mentioned their *expanded capacity for future research* based on their experiences with the interdisciplinary team; as collaborative groups progress in their work, they may find new avenues for future research and also may have some members splinter off launch new projects with other members of the existing team.

The institutional/external level. At the institutional/external level, influences on the group tend to be in the *availability of funding* and also the presence of *institutional supports* for the interdisciplinary team. Participants in the current study suggested they formed groups based on a need to do research, get grants, and publish (i.e., MFIIRC individual level, career

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advancement) but tailored research questions and member selection based on the request for

proposals from funders (i.e., MFIIRC, institutional/external level, available funding).

Participants also said the structures and functions in place at BSU to facilitate interdisciplinary

research were helpful but collaborative researchers could benefit from expanded support (e.g.,

administrative help, clarification of RPT processes). Benefits from interdisciplinary work at the

institutional level include revenue along with any publicity research projects may attract. At the

external level, the benefit of interdisciplinary research is *advancement toward a problem solution*

of particular interest to the funder (or society).

Linking MFIIRC Elements, Findings, and the Literature

The following sections discuss the MFIIRC factors in relation to each other, my findings,

and extant literature. The section opens with an observation about how factors are arrayed within

the model and, using those broad categories, I illustrate linkages between model elements and

their influence on groups. Throughout, I refer both to my findings and to a range of literature

including work on collaboration, interdisciplinarity, higher education institutions, and group

processes/development.

An interesting dynamic is illustrated by the MFIIRC (Figure 4): In terms of

antecedents/inputs, the number of factors is fewest at the institutional/external and the individual

levels whereas that is where interdisciplinary research benefits tend to accrue. For research teams

themselves, the opposite is true: The majority of antecedents and inputs factor into the model at

the group level yet there is only one factor in their potential outcomes category - expanded

research capacity. In the following sections, I discuss group level and non-group level factors of

the MFIIRC in relation to my findings and extant literature to illustrate how antecedents/inputs

link together and can contribute to desired outcomes within the model.

External/institutional and individual level factors. Funding, institutional supports, intrinsic motivation, professional networks, and career advancement, although situated in different places within the MFIIRC, are closely linked. Each factor must converge in order for an interdisciplinary group to launch its research: Funding must become available and someone's network helps to form a group which then writes a proposal. Motivated both by desire to investigate a problem domain and requirements for career advancement, the group can make use of institutional supports (e.g., grant writing help) to facilitate their funding application and eventually, the work of the research project.

Faculty participants in my study were clear that grant getting and publishing were priorities one and two in terms of reappointment, promotion, and tenure at Bridgetown State. As Dr. Lebowski said, "you're dead in the water" if you, as a faculty member, are not bringing in external dollars. Indeed the push is not simply for funding but for "big money" (Dr. Loomis, Case Two) and generally STEM-related projects are the ones fetching grants of the highest value.

In terms of reappointment, promotion, and tenure criteria, getting grants and publishing are top priorities for faculty. One's appointment and one's field of study determines how much of both are required. For Dr. Züppe, who is on a research appointment, his grant getting and publishing criteria are stringent: he needs to bring in a lot of money and publish a minimum of two articles per year; if he wants to be considered "excellent" according to his RPT criteria, he must publish five articles per year. Dr. Kerabatsos, a postdoc, is funded on "soft money" (i.e., grant dollars). He is responsible for bringing in money that will pay his own salary and publishing articles based on his funded research. These are not uncommon requirements in many fields and faculty know this going into their jobs. What some participants were unprepared for,

however, was the intense focus on grant getting in fields where securing external funding, especially large grants, is not normally a significant portion of the job (Bakken & Simpson, 2011). Both Dr. Gunadi and Dr. Lebowski were surprised at the pressure they were placed under to bring in research money and to collaborate with, as Dr. Lebowski put it, "STEM friends." Neither had anticipated being income-generators for the institution, but as their time at BSU has progressed, the pressure for outside funding has intensified: no grants, no job.

Bennett and Gadlin (2014) charged, "The lure of research funds and the publicity-garnering successes of some collaborative scientific efforts (e.g., The Human Genome Project) have led many academic institutions to actively promote the formation of scientific teams and collaborative ventures" (p. 357). The problem researchers face, however, is that "norms, values, policies, and procedures in their field, their department, or their university are misaligned with the messages being sent" (Bennett & Gadlin, 2014, p. 357). Dr. Gunadi's and Dr. Lebowski's experiences at BSU are a good example of institutional messages being misaligned with norms in their own fields and departments. As a social scientist, Dr. Lebowski is accustomed to writing books and doing extended fieldwork on her own. Her work is normally supported by small grants - certainly nothing to the extent of a multi-million dollar NSF award. Similarly, although Dr. Gunadi has a joint appointment in a STEM department, his tenure home is a social science area and again, he was unaccustomed to writing large grant proposals. He mentioned in his first interview with me that he had "been naïve" when he thought he would be able to pursue a line of inquiry without much fieldwork and in the absence of external funds.

Reappointment, promotion, and tenure policies have not maintained pace with where research is today and the consequences can be detrimental to knowledge-creation and innovation: "If self-preservation limits the questions posed by early-career academics, a perceived career risk

is as damaging as a real one to new transdisciplinary initiatives. Thus, institutions should address

the source of this perception whether real or specious" (Fischer, et al., 2012, p. 311). Schmidt

and Moyer (2008) argued, "Tenure committees often do not appreciate publications in out-of-

discipline journals and may not value collaborative work. Timescales for promotion and metrics

of success may be incompatible in different fields" (para. 2). If Bridgetown State plans to

continue pressing faculty to get external grants, recognizing that their own systems can be

deterrents and subsequently adjusting them to be supports, would be valuable to consider for

both researchers and the institution. Trower (2008) argued extending the amount of time one is

allotted in which to achieve tenure could help to support interdisciplinarity. Like Trower, Fischer

et al. (2012) recommended using alternate tenure timelines and also suggested broadening the

scope of acceptable research outcomes (e.g., reports, decision support tools) could be useful in

supporting interdisciplinary work. Fischer and her colleagues acknowledge, however, there is a

"lack of precedent for evaluating nontraditional accomplishments" (p. 311) so simply changing

what is written in RPT guidelines is insufficient: new evaluation models for faculty productivity

at BSU must also be created.

Ten years after the National Academies of Science called for institutions to support

interdisciplinarity through altering RPT policies (NAS et al., 2004), the National Research

Council (NRC) of the National Academies (2014) released another report about convergence, an

enhanced form of interdisciplinary research, echoing the same concerns from 2004:

> Adequately accounting for participation in convergent research during promotion and
> tenure decisions remains a topic of great interest… A reward structure that emphasizes
> individual investigator-driven research and publication and questions of how credit is
> assigned for multi-investigator-led projects represent widely acknowledged challenges to
> any form of interdisciplinary or collaborative research (p. 54).

The NRC suggests, "embedding support for interdisciplinarity in the promotion and

tenure process" (p.54) and, short of a "radical reorganization" (p. 60) of institutional structures to

support interdisciplinarity, the NRC suggests promotion and tenure policies must both recognize interdisciplinary work and "have unique evaluation criteria" for faculty conducting interdisciplinary research (p. 11). The NRC further suggests that academic leaders (i.e., institutional decision-makers) "develop policies, practices, and guidelines to support and evaluate convergent and disciplinary research equally" (p. 11).

Adjudication of RPT packets extends beyond institutional walls and relies heavily on referees from a candidate's field. Written reviews from expert colleagues provide a critical component of one's RPT file problems and problems can be encountered by faculty when outside experts, not accustomed to reviewing interdisciplinary work, are responsible for evaluating it. Although making recommendations to entire disciplines is beyond the scope of the current study, something to note for future research is the idea of looking at the norms for ad-hoc RPT reviews from field to field and understanding how a field's culture and perceptions surrounding mono- versus interdisciplinary work influence refereeing of packets. Some participants in my study (i.e., Dr. Gunadi, Case One, Dr. Loomis, Case Two, and Dr. Lebowski, Case Three) had less trouble at the institutional level than they did with outside reviewers and, as such, prepared more extensive packets than other colleagues may have had to put forward because their activities included interdisciplinary collaborations in fields where faculty usually work not only mono-disciplinarily but also alone.

In the preceding section I described linkages between external/institutional and individual level factors influencing research collaborators in relation to my findings and the literature. Next, I turn my attention toward the group level influences illustrated in the MFIIRC.

Group level influences. My participants discussed a number of factors influencing their work on research teams and when I distilled the data, five major influences emerged:

communication, *leadership*, *place*, *resources,* and *social/affective factors.* What follows will illustrate how my findings align with literature about interdisciplinarity, collaboration, and also what influences groups.

      Communication. Participants from all cases discussed the importance of communication as a means both to stay in touch and to understand other team members' ways of knowing. Good communication skills like being polite, efficient, and keeping all members "in the loop" were important to participants. Having clear meeting agendas and communicating expectations, especially to graduate students, were things participants also valued.

      To appreciate how people from other disciplines think about problems and the sorts of methods they use required teams to employ language-learning skills. Participants from each case used terminology like "learning the language" of another discipline (Jenny Miller, Case One; Dr. Kerabatsos, Case Three) or "translating" concepts (Dr. Brandt, Case Three; Laurie Stroud, Case Two). Language learning was clearly a challenge for teams but was an important skill to have: "You have to invest in understanding how they think and what their language is. They have to invest in you and you have to invest in them. That makes successful teams" (Dr. Brandt, Case Three). Jenny Miller (Case One) said, "The push right now in a lot of different areas is to have the skill set to be able to speak the technical language, the jargon, from other disciplines." My findings suggest teams need to invest time in disciplinary language learning because the result is deeper understanding of the overall project and better communication between group members.

      Communication is critically important for interdisciplinary groups; it "ties interdisciplinary collaborators to one another but also to those on whom they depend for support…and to those who depend on them for research solutions" (Crowley, Eigenbrode, O'Rourke, & Wulfhorst, 2014, p. 6). Nash (2008) and Kozlowski and Ilgen (2006) also found

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communication was an important influence on group outcomes. Further, the literature is replete with references to the challenges interdisciplinary teams face but must overcome, in terms of learning the language of their colleagues (Campbell, 2005; Crowley, Eigenbrode, O'Rourke, & Wulfhorst, 2014; Cummings & Kiesler, 2008; NAS, 2005; Schmidt et al., 2012).

I liken disciplinary language learning and integration to the process of learning to play the piano: First one learns to read music and then may tentatively play some notes in the treble clef. One might then attempt some bass clef notes and perhaps then play with both hands together. Eventually, with enough knowledge and practice, one should be able to play elaborate and complex pieces of music. Usually, before one can attempt Beethoven, one must first be able to integrate both the reading of the music and the motor skills necessary to manipulate the keyboard. Similarly, integration in interdisciplinary research requires a painstaking learning of language before the more high-level melding of work can be done. Groups who do not take the time nor make the effort to engage in disciplinary language learning may achieve some results but run the risk of not fully achieving integration, which is the ultimate goal of interdisciplinarity and ties directly to an institutional/external level outcome of the MFIIRC: advancement toward a problem solution.

Another important aspect of communication is technology. All participants in my group made good use of technology to (a) stay in contact with group members (e.g., Skype, email) and (b) actually conduct the work of the project (e.g., Google Drive). Cummings and Kiesler (2008) pointed out however, "differential use of technology within a virtual organization can present a barrier to open exchange and discourse" (p. 8). Fortunately, none of my participants reported trouble coordinating knowledge exchange among the group but Cummings and Kiesler (2008)

offered the following example of how teams, particularly those who are geographically

dispersed, can struggle:

> If only some members of the virtual organization have easy access to large screen video conferencing, or only some of the members check the wikis, or only some of the members use IM [instant messaging] regularly, then the distribution of knowledge will be uneven (p. 8).

Principal investigators who understand how differential technology use can influence

their group could possibly mitigate its effects by limiting the number of places critical

information is shared and also by ensuring group members have equal access to technology, if at

all possible.

Place. According to my participants, group members get to know each other more

quickly and perhaps better when they are physically together over time. All of the groups I

interviewed had spent extended amounts of time together. Two groups traveled abroad together

and one group is located along the same hallway. Nash (2008) suggested locating collaborators

together as beneficial for the group and Cummings and Kiesler (2008) also suggested teams

benefit when members are located near each other. They suggested, "distance reduces

spontaneous interaction, which acts as a kind of 'glue' for collaborative relationships" (p. 3).

Mike Myers (Case Two) remarked on the team's ability to "hang out and brainstorm" frequently

because of their offices being located in the same area. Earlier, in Chapter Two, I referred to

Rhoten's (2004) critique of institutions and their handling of interdisciplinary work, which

relates, in part, to the lack of opportunities for consilience. Wilson (1998) described consilience

as a "jumping together of knowledge by the linking of facts and fact-based theory across

disciplines to create a common groundwork of explanation" (p. 8). The more time group

members spend together, the more opportunities there are for casual conversations or informal

meetings (Cummings & Kiesler, 2008), which ultimately can lead to consilience. Groups that

must rely on planned meetings to bring members together have fewer opportunities for spontaneous generation of ideas with their colleagues.

Although Case Three does have members who are not from BSU and who did not travel with the group, the majority of the team did spend time abroad together. Research suggests, however, that if people have worked together in the past, they are more likely to work successfully with each other in the future (Cummings & Kiesler, 2008). Although Dr. Sobchak has not worked with several members of the team, he has worked successfully with Dr. Kunkel who, in turn, has worked successfully with many other people from Case Three. So, the negative impact of Dr. Sobchak's inability to travel with the group may be mitigated by his prior successful working relationship with at least one member of the team.

Resources and leadership. Discussing resources and leadership together here helps to illustrate the links between the two factors and also their position within the domain of principal investigators. Although everyone can take a leadership role on a team from time to time, PIs are, in general, the people responsible for forming the team, applying for funds, and allocating resources. Ensuring the best people for the job are on the team and also that resources are allocated appropriately are responsibilities of the PI. Leadership and resource issues challenged both Drs. Gunadi and Webb (Case One) during the course of their project: Dr. Gunadi became a grant administrator and found he had much to learn in a short period. Dr. Gunadi also expressed some regret at how the team was formed and suggested he would carefully consider "fit" when forming his next team. Dr. Webb expressed frustration at how resources, particularly salary, is allocated across PIs on his team. Although neither issue will derail the team, certainly having a drastic reduction in participation by other PIs on the team (Drs. Smith and Davis) has limited the

scope of the work and the potential for integration and advancement toward a problem solution (MFIIRC, institutional/external level factor).

Resources and leadership are also closely linked with an MFIIRC desired outcome: experience. In this study, the PIs who had prior experience with interdisciplinary work reported less challenges in terms of understanding how to approach a cross-disciplinary project. For example, Dr. Gunadi (Case One) had several years of experience with interdisciplinary work in his doctoral program and said he was challenged most by administrative aspects of his PI role rather than the interdisciplinary work itself. Unlike Dr. Gunadi, Dr. Lebowski (Case Two) had conducted research independently for the majority of her career and this group is her first cross-disciplinary endeavor. As such, she is responsible not only for her portion of the interdisciplinary work but also forming an understanding of how to engage with STEM researchers, manage language barriers, and conceptualize methodological differences, for example.

Experience in interdisciplinary groups can be especially important for graduate students because their time is spent not only apprenticing as researchers but also being socialized to interdisciplinary work by group leaders (Borrego & Newswander, 2010; IGERT, 2014; Salter & Martin, 2001). The only preparation any of my participants had for how to do interdisciplinary work was in graduate school (Dr. Gunadi, Case One; Dr. Züppe, Case Three). Otherwise, people were learning as they participated on an interdisciplinary team for the first time including some of the PIs (Dr. Wynn, Case Two; Dr. Lebowski, Case Three). Dr. Züppe cautioned that it is "too late" to learn interdisciplinary skills after graduate school when one is already "in a position to be a PI," because time spent determining how to work interdisciplinarily is time that could be spent on other important tasks. Dr. Lebowski (Case Two) also suggested graduate school is the ideal time to learn how to engage in interdisciplinary work. Dr. Gunadi benefitted from

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interdisciplinary training during graduate school yet still had many facets of collaborative work to learn about when he became a PI. In particular, Dr. Gunadi found adjusting to being a researcher and a project administrator challenging.

Others outside this study also recognize the importance of leadership and preparing graduate students for interdisciplinary work. The Integrative Graduate Education and Research Traineeship (IGERT) is the NSF's "flagship interdisciplinary training program" and funds projects on which PhD students can work and through which they can gain interdisciplinary experience (IGERT, 2014, para. 1). Programs like IGERT prepare graduate students for interdisciplinarity in both academic and non-academic careers (Schmidt et al., 2012) by helping them "integrate knowledge across disciplines, cultures, and organizations" (p. 296). Formal programs like IGERT and, as my findings suggest, interdisciplinary research experiences in general, help combat "narrow training in graduate school" (Schmidt et al., 2012, p. 297) so by the time students graduate, they are capable of working across disciplinary boundaries. Training to work in an interdisciplinary fashion does exist for those who did not receive it during graduate school. Although programs are available, almost none of my participants had heard of them. The one person who had, Dr. Gunadi from Case One, decided against participating because he felt his group was "going along fine" and did not need to spend time doing training.

Social/affective factors. When I reviewed my findings and how they mapped to the original MFIRC, I found substantial data under the organizational values and identity sub-factor. In the following sections, I parse out some of those findings and describe how I arrived at the examples I listed under shared values in the new MFIIRC: collegiality, commitment, competence, fairness, mutual interest in a problem, and trust.

Collegiality, commitment, and competence. Much of the organizational values and identity data had to do with the more affective aspects of group work (e.g., getting along, being willing to share ideas, working hard). With the exception of some disappointment about Drs. Davis and Smith reducing their involvement with the group from Case One, all participants in my study had good things to say about the collegiality of their research teams. Participants also had good things to say about the high level of scholarship their fellow team members were capable of and the PIs from Cases One and Two were especially happy with the performance of their graduate students. When I considered the kind things people said about each other, the effort people were reported to be putting into their work, and the high level they were performing at, I created sub-terms called collegiality, commitment, and competence.

Fairness. The teams I spoke with all reported that resources and credit for work to date have been allocated fairly. Aside from one issue with the way summer salaries are paid in Case One, all participants suggested resources had been divvied up appropriately. Dr. Kerabatsos said he had actually been given "more opportunity for input" on the resource allocation process than he had even chosen to participate in. I asked participants how decisions about resource and credit distribution were made and normally people responded that a discussion had taken place. I did not hear from anyone that they had been allocated resources but had no idea how the decision making process had unfolded. The graduate students also had some understanding that resource allocation resulted from discussions between PIs, even when the students had not been privy to those conversations because they were not yet on the project. Transparency in decision-making seemed to please participants and in the one instance where it did not happen that way, there was frustration. Anya Fraise from Case One expressed disappointment when a research related funding request she submitted was denied. When I asked her about the incident, she said she had

not explored the issue further with her advisor/PI because she was not sure, at the time, whether or not that would be appropriate.

Mutual interest in the problem. All participants I interviewed mentioned their deep interest in the particular problem their team was attempting to study. Each of the groups researches an issue that has multiple implications for people and regions in America and abroad and all participants recognized the importance of their work to the wellbeing of others. Laurie from Case Two said, about her group's work, "we're all trying to work toward a common goal and we all see the benefit in that. What we're working with is pretty intense so knowing that, we all are very supportive and are trying to shed some light on that mystery." Despite disciplinary differences, sharing interest in and concern about the group's common research problem seemed to help teams come together and stay motivated during challenging times in the research process.

Trust. Working on an interdisciplinary team requires a leap of faith. Given the stringent criteria against which faculty are measured and the standards that graduate students must meet, projects that are not successful can have a devastating effect (e.g., failed relationships, lack of findings, lack of publications). Bennett and Gadlin (2013) said, "Establishing organizational trust provides a platform for direct communication and the foundation on which vision can be articulated, change implemented, and conflict managed" (p. 360). Fortunately, participants in my study have had good experiences within their current research groups: students have faith in their PIs, PIs rely on their students, and co-PIs turn to each other for guidance and support during the research process.

My arrangement of findings within social/affective factors of the MFIIRC is similar to what Nash (2008) said about group level influences. He suggested communication, trust, and

"characteristics consistent with a transdisciplinary ethic" (p. S137) were important to group

success. The characteristics are as follows:

> Openness and respect for different disciplinary approaches; Desire to work in collaborative teams involving multiple disciplines Broad-gauged contextual thinking; Interest in using multiple methodologic tools; Intellectual curiosity and willingness to take intellectual risks; Tolerance for uncertainty; Self-assuredness and non-defensiveness when not knowing; Assertiveness in seeking clarification; Optimism, tenaciousness, and willingness to operate; without clear, immediate rewards; Ability to lead and foster mutual respect and trust in others (p. S137)

Nash said the factors are based on "observational data that have a very small evidence

base" (p. S136), which is interesting because they bear some similarity to my own findings,

which also come from a small evidence base. Nash's focus was on interdisciplinary training

whereas this study's focus is interdisciplinary collaboration. As seen from the literature and my

findings though, interdisciplinary research groups serve as both work groups *and* training

grounds. As such, Nash's list is relevant to my own study given it also touches on some of the

affective components of working in a team. Kozlowski and Ilgen (2006) studied factors relating

to group success too and determined several areas influencing teams. Their list included team

cognitive processes and structures; interpersonal, motivational, and affective processes; and

action and behavioral processes. Although the authors acknowledge some of the levers or

supports for each process are ill defined, they do offer some examples. Under cognitive

processes and structures, they suggest *shared experience* can be helpful. Under interpersonal,

motivational, and affective processes, *interpersonal skills, conflict management skills, and trust*

are identified. Finally, under action and behavioral processes, the authors suggest *coordination,*

cooperation, communication, and member *competencies* are all influential (Kozlowski & Ilgen,

2006).

Study Implications and Recommendations for Practice

Findings emerged from this study that could influence theory, research, and practice. First I discuss implications for theory then share implications and make recommendations for practice. Finally, I share ideas for future research.

Implications for theory. The main contribution of this study is a clearer model of factors influencing interdisciplinary collaboration. Much has been written about interdisciplinarity from numerous perspectives but to date, models have not necessarily aggregated the variety of factors influencing groups. The MFIIRC accounts for individual, group, and institutional level influences and also illustrates antecedents to and desired outcomes of interdisciplinary research. Understanding precursors and outcomes is helpful because people funding, engaging in, or working at institutions to support interdisciplinary research may not be aware of the breadth of influences on groups. Having that information in a clear and concise format may be helpful to prompt people to consider influences they may not know exist but are indeed at work.

Implications for practice. Three recommendations for practice emerge from this research: First, given what I now know about interdisciplinary research at BSU, I believe my responsibility is to share the MFIIRC with BSU research administrators (e.g., Vice-President for Research's office, administrators responsible for interdisciplinary research at BSU, contracts and grants administration office). Second, I will work to disseminate my findings beyond BSU as widely as possible to contribute to the knowledge base about interdisciplinarity. Finally, I will share an abbreviated report of my research with my participants so they can see how their involvement in the study has contributed to the research on interdisciplinary collaboration.

The next sections include implications and recommendations for both the institution and for interdisciplinary groups. I begin by discussing how BSU can better support interdisciplinary research and end by sharing implications and recommendations for groups themselves.

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Institutional level implications and recommendations. Bridgetown State has a number of supports in place already for interdisciplinary researchers. My recommendation is that the institution at least maintain, if not expand, its offerings because participants in my study remarked how useful a number of the university structures were in terms of supporting their efforts both to find collaborators and conduct their research.

Bridgetown State University, however, could improve its support for faculty who engage in interdisciplinary work by encouraging departments to make their RPT processes more transparent in terms of how interdisciplinary work will be assessed. My findings suggest faculty are either (a) already accustomed or (b) are adapting to BSU's intense focus on getting external research dollars. What is less clear for many participants, however, is how best to navigate the RPT process in departments where large interdisciplinary groups and co-authored publications are not the norm. I asked researchers how interdisciplinary work was assessed in their home departments: for STEM participants, interdisciplinary work was not only rewarded, it is the norm and is expected. Social scientists, however, had extra work to do to ensure their RPT packets would be judged favorably by outside reviewers who may be coming from an institutional and/or disciplinary context where interdisciplinarity is not such a focus. Dr. Gunadi, Dr. Lebowski, and Dr. Loomis all mentioned they had to be mindful of their disciplinary norms and outside reviewers. They all ensured they had a suitable amount of individually authored publications to satisfy reviewers who may not look favorably upon group authorship. To do so, however, they had to be strategic and do extra work that STEM colleagues, in this study, did not. Interdisciplinary work should not be unduly burdensome; navigating the RPT process seemed to pose more challenges for the social scientists in my study than for my STEM participants.

The interdisciplinary supports currently in place at BSU will be insufficient to serve the numbers of faculty the institution hopes to entice into interdisciplinary work. Bridgetown State must maintain its current offerings, create new structures and functions (e.g., training programs, offices to assist with interdisciplinary grant administration), and determine how to help collaborative faculty navigate the RPT process – especially those in fields where interdisciplinarity is not the norm. Appropriately supporting faculty must be part of an institution-wide commitment to shift toward a culture of interdisciplinary rather than, as Rhoten (2004) suggested, a "piecemeal, incoherent, catch-as-catch-can" (p. 6) effort. If BSU wants to reap the rewards of interdisciplinary research, and there are many to be had, the institution itself must invest time and resources into ensuring the infrastructure to support collaborative work is both sound and sustainable.

Group level implications and recommendations. Four group-level implications emerged from this study: graduate student involvement on interdisciplinary teams, colocation of group members, communication, and interpersonal interaction. I expand on and make recommendations to address each in the following sections.

Graduate student involvement. Graduate student socialization into academic work happens on the job so ensuring they have authorship opportunities is important. However, opportunities for students to be lead author papers or conference presentations should not come at the cost of faculty members who also need lead authored publications and presentations for RPT purposes. At least one program on campus has a policy in place to ensure faculty receive credit when their graduate students are first author on a co-written paper. Bridgetown State should consider expanding that policy across campus (a) to prevent faculty taking advantage of

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students regarding their contribution to authorship and presentations and (b) to incentivize writing papers, or presenting at conferences, with students.

Colocation of members. Both my findings and the literature (Cummings & Kiesler, 2008; Nash, 2008; Rhoten, 2004; Rhoten 2003) suggest being together is a precursor to group success and can build necessary bonds to sustain the team when people return to their locations again. In the current study, teams who traveled spent, at minimum, a week together, which aided group bonding and facilitated the teams' ability to gain deeper knowledge of how component parts of their research fit together. The team in this study who did not travel together (Case Two) was the team whose offices were collocated along the same hallway so their group's bonding and the advancement of their work were facilitated by daily interaction. To maximize group bonding and interpersonal relationship development, PIs leading groups who are geographically dispersed (at the campus level or beyond) should arrange for their teams to spend as much time together as possible.

Teams who are not co-located and also cannot travel together may be more challenged to do interdisciplinary work. Research has demonstrated people favor face-to-face contact and prefer that technology mediate communication only after in-person connections have been made (Brown, Poole, & Rodgers, 2004). Some researchers, like Dr. Sobchak from Case Three, will not be negatively affected by being physically apart from colleagues. Others, however, might find their group's development, disciplinary language learning, and informal communication may suffer if members do not make concerted efforts to overcome those challenges. Again, a job for the PI is to inform the team about potential roadblocks and encourage everyone to take responsibility for working to overcome them. A further step could be taken to facilitate the group's communication and development: A PI should examine the team to identify *hubs* and

bridges (Rhoten, 2003) and engage those people to work in their unique ways. Hubs are described as the people within a group who have the most connections within a given context (e.g., a research center) and are often known as content experts in their particular field. Bridges are important members of interdisciplinary teams and are the ones with the most interdisciplinary connections. Rhoten suggested bridges are often graduate students (e.g., Laurie Stroud, Case Two who found herself playing the role of "translator"), technicians, or methodologists. Engaging hubs to bring in connections and bridges to span boundaries between people unfamiliar with each other is an important strategy for any PI, but especially for those wishing to mitigate some of the effects of geographic disbursement.

     Communication. Bracken and Oughton (2006) wrote, "Common understanding derived from shared languages in turn plays a vital role in enhancing the relations of trust that are necessary for effective interdisciplinary working" (p. 371). Ulrike Beisiege, while working for the German Research Foundation, was interviewed by Ledford (2008) and was quoted as saying, "it is astonishing how little communication there is in the scientific community concerning planning of the project and talking about who is doing what" (p. 682). That communication influences interdisciplinary groups' success is clear from the literature (Cummings & Kiesler, 2008; Klein, 2008; Ledford, 2008; Bracken & Oughton, 2006; Brown, Poole, & Rodgers, 2004) and also emerged as a finding in this study. Logistics, as raised by Beisiege in Ledford's article, are just one area where communication is critical. The language of other disciplines is also a critical component of interdisciplinary group communication. Participants in my study seemed surprised that disciplinary language learning was necessary before they could begin to have conversations that would advance the work of their projects. Methodologies shape disciplines, and they are different between social sciences and STEM so understanding how methods shape

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question-asking and approach is important. If PIs understood the degree to which communication was influential over their group, they may be encouraged to watch for potential problems like differential technology use (Cummings & Kiesler, 2008), language barriers, or information gaps/bottle-necks (Bracken & Oughton, 2006; Bracken, 2005).

Training is available for interdisciplinary groups and some programs focus specifically on communication and language learning (O'Rourke et al., 2014), but how to motivate PIs to invest time in training, especially when much of it has to do with "soft skills" (Dr. Gunadi, Case One), is unclear. In the absence of training on communication, PIs are advised (a) to inform group members that language learning will be an issue and (b) ensure they build time into research plans for the process of learning other disciplinary languages. Unfortunately, how much time to allocate for the process is not entirely clear and will likely vary on a group-to-group basis. Knowing that the research will be hindered without understanding each other's language and ensuring all group members know about the concept of language learning is important so people are not surprised when language challenges arise nor are they discouraged from taking the time to listen to and learn from each other.

Interpersonal interaction. Perhaps the most nebulous implication emerging from this study is that PIs need to be aware of how interpersonal relations influence groups and be able to nurture behaviors that support positive interaction. Researchers have created long lists of characteristics (Nash, 2008) or processes, levers, and supports (Kozlowski & Ilgen, 2006) that facilitate successful teams and they all read like a how-to manual for "getting along with others." My participants discussed some of these same characteristics and Dr. Gunadi illustrated the importance of getting along when he lamented how they had put his group together and that it was based on people's disciplinary expertise rather than "fit." How well people fit into a group,

how they interact with others, and how they perform are important to teams (Nash, 2008; Kizlowski & Ilgen, 2006) yet they are also the same characteristics that can be difficult to discern about people until after the group has already been formed. Although, personality traits or interpersonal abilities may not be the first characteristics that emerge when considering potential collaborators, I recommend PIs factor "fit" into decisions about team composition from the outset. Further, I recommend PIs take advantage of any training or team development sessions available to their group. Overlooking what Dr. Gunadi (Case One) called "soft skills" can be detrimental to groups so building teams carefully, taking advantage of training, and also alerting group members to the potential pitfalls of poor interpersonal interactions is incumbent upon PIs.

Avenues for future research. The first project(s) emerging from this research should be a test of the new model to understand (a) whether the factors in the MFIIRC do describe the experiences of interdisciplinary groups, (b) what additional factors, or lack of constraints, help groups move from input/antecedent to outcome (i.e., what happens at the level of the arrows in the MFIIRC), and (c) testing the model with groups who have not been as successful as the three studied here (i.e., test the model on struggling or failed groups).

Another way to extend this project would be to include humanities scholars, which would offer one of the first studies of their role in interdisciplinary groups and the influences on those groups' success. As the trend toward interdisciplinarity continues, bringing humanities into the fold in the same way social scientists have been is only a matter of time. In some areas incorporating humanities has already begun – the lead author on O'Rourke et al.'s (2014) publication about communication in interdisciplinarity is himself a philosopher and brings a philosophical lens to the issue of language learning and interpersonal communication. Another

way to extend the current study would be to include research groups not based at BSU as a way to explore the influences of different institutional contexts and/or determine how well the MFIIRC fits to describe those groups' experience.

For several PIs in my study, the threat of unfavorable RPT packet reviews by external referees caused them to do extra work to satisfy disciplinary norms. Given the pressure for faculty to get grants and the availability of money earmarked for interdisciplinary work, people who had not previously engaged in cross-disciplinary research are now doing so at increasing rates. As such, they may encounter similar issues to the three PIs in my study for whom interdisciplinary work was new and whose disciplines were not yet equipped to evaluate fairly. An interesting possibility for research emerging from the current study is to examine how disciplinary norms influence the way ad-hoc RPT reviews are conducted. A study like the aforementioned one could begin with an historical analysis of the use of external referees for RPT adjudication, the ways in which those reviews are discussed within the discipline, and how norms (Bennett & Gadlin, 2014) for RPT file review are passed down, over time, throughout a field. Understanding each of the aforementioned factors would be important in determining not only how interdisciplinarity is viewed within a field but also, and perhaps more importantly, who has the power among members to influence perceptions and trigger the expansion of evaluation methods for interdisciplinary work called for by Fischer et al. (2012) and Schmidt and Moyer (2008).

Finally, and perhaps most pressing for BSU, would be a study of the institution's RPT norms, policies, and procedures that could delve into reasons why RPT guidelines are the way they are, why any have changed (if applicable) to support interdisciplinarity, and what barriers people face in making changes. Studying academic leaders' (e.g., department chairs, Deans, VP

Research, Provost) attitudes and perceptions around interdisciplinarity in general, and at BSU specifically, would be necessary to understand how decision-making happens and who holds power to create change within the institution.

Study Limitations

Participants in this study were not a racially diverse group. Of the 15 people interviewed for this project, only one identified as a Person of Color and she reported that her racial heritage was a significant advantage to her on the research team because it meant she was one of the few people in the group who could speak the language in the country where their study is located. Given the focus on race in higher education, and the underrepresentation of some minority groups within STEM (Hurtado, Newman, Tran, & Chang, 2010), including some analysis about the influence race on people's experiences in their group may have been advantageous to the study.

Similarly, of all PIs in the current study, only one was a woman. Again, there is a large body of literature about women higher education so having more women PIs would have been advantageous in order to explore if or how their experiences are different than their male counterparts.

This study could have been more robust had I been able to include everyone in each research group. The people who chose not to participate may have had differing views on the success of the group, for example. Additionally, including people who did not meet criteria for this study but were members of the research groups may also have provided interesting findings and incorporating them into future research could be beneficial.

Conclusion

The value of interdisciplinary research is unquestioned. Teams from various disciplines can tackle large, complex problems in ways individual researchers simply cannot. Although

interdisciplinary research is exciting, intellectually stimulating, and financially lucrative, there are myriad barriers challenging multidisciplinary teams. Investigators have examined teams from a variety of perspectives and this study looked specifically at the MFIRC to assess how well it described the experience of interdisciplinary research groups at Bridgetown State University. Findings suggested the original MFIRC was not an ideal model so a new version, the Model of Factors Influencing Interdisciplinary Research Collaborations, was created. The MFIIRC (Figure 4) illustrates individual, group, and institutional level factors that influence interdisciplinary teams and show also showing antecedents to and desired outcomes of these collaborations. Findings from this study demonstrate that BSU, in terms of its interdisciplinary efforts, shares similar challenges and successes reported within extant literature. Recommendations for the institution, emerging from this study, are twofold: First, BSU should maintain, even expand, already existing supports for interdisciplinarity (e.g., centers, writers, databases). Second, BSU should encourage departments to make their RPT policies more transparent so faculty understand how interdisciplinary work might be differently evaluated from traditional research. The institution could also encourage the creation of evaluation processes that fairly assess faculty productivity resulting from interdisciplinary work. Recommendations for interdisciplinary groups include ensuring teams have time together over an extended period of time and ensuring communication is good. Good communication includes having teams learn each other's disciplinary languages and also monitoring the ways technology is used and information is shared across the group. Finally, PIs must be cognizant of "fit" when assembling teams and should encourage positive interpersonal behaviors, which, in turn, support the collegiality and functionality of the group.

APPENDICES

Thanks for agreeing to help me pilot the instrument. We'll do the interview and I'll ask you about your experience of the actual discussion at the end. Remember I can pseudonym or mask your group's focus and we can re-visit that again at the end so you feel comfortable with what's been captured in our discussion.

1. Tell me about the project. What do you study? What is the project's goal/focus?
2. How did you come to be involved with this group?
3. How many people are on the research team? What are their roles?
4. What's your role on the team?
5. What disciplines are involved?
6. How much experience did you have with the disciplines involved prior to this project?
7. How is the project funded? How much funding/grant amount? How long is the funding meant to last?
8. Organizational Values and Identity: Tell me about your sense of affiliation to this research group. By that I mean, do you have a sense that these are "your people?" What about people from outside your discipline? How much of a sense of "oneness" or "kinship" do you feel with them?
    a. How aligned are the group's values/practices with your own?
9. *Assessing and Supporting Faculty Work*: Can you tell me about how research is rewarded in your home department? How do you perceive collaborative work to be assessed versus research done by a lone investigator?
    a. Who makes decisions about the merit of your research related to T&P? (for faculty only)
    b. In terms of career advancement, what are the risks and rewards for faculty who take on collaborative work? (for
    c. Professional Development Opportunities: What have you learned as a result of your involvement with this research team?

10. *Professional Development Opportunities*: What have you learned as a result of your involvement with this research team?
    a. How has working with this group influenced your professional development?
    b. What benefits have you had from working with this group?

11. *Professional Networking Opportunities*: Can you tell me about how someone's professional network (e.g., your own, the PI's) has played a role in formation this collaborative group? How, if at all, has your own professional network changed since working with this group?
    a. How would this team and its work be different with/without the influence of someone's professional network?

12. *Communication and Information Technology*: Tell me about how people communicate in your group and how effective you think that is. How do disciplinary boundaries influence communication? What role does technology play in your group's communication?

     a. What are some of the biggest challenges to your team's communication?

     b. What works best in terms of your team's communication?

13. How did your group come to its research question(s)?

14. How did your group decide how to distribute work?

15. How did your group decide how resources would be distributed?

16. How did your group decide how credit would be distributed?

17. Do you have the sense you're being trained to do interdisciplinary work? (Were you trained to do interdisciplinary work?)

18. Is the work getting done?

     a. Like you promised in the grant?

     b. The way you want it to?

     c. To its potential?

19. Anything else I should know or that you're surprised I didn't ask that may be relevant?

Interview Protocol for Round Two

1.

2. The importance of professional networks is described in the literature and was also a theme in this study. If you needed someone with expertise in an area but couldn't find someone within your own network, what process would you follow? (I'm looking specifically for information about how you'd go about locating someone e.g., internet search etc.).

     a. Is it more important to work with someone you know or to have someone on your team? (i.e., if you can't find someone within your network, will you work with a stranger or would you just not include that information/area of expertise in the project?)

3. Regarding working with people from other fields, participants in my study reported "muddling through," trial and error, etc. How much do you think a team could benefit from training in how to work interdisciplinarily?

     a. How much is the "muddling through" an important part of the process? What's to be gained/lost through training?

4. Interdisciplinary collaboration is hailed as a way where disparate people come together to create something new that would otherwise not have been possible. I heard some reports of "he did his part then I did mine" or "they took the lead on that and I was only involved when it was my turn" etc. Similarly, there's a difference between lining up a bunch of ingredients on the counter versus manipulating those ingredients in a specific fashion and winding up with a pie (i.e., something greater than the sum of its parts). How much of a sense do you have that your work with this project has been "pie baking" versus "lining up ingredients?"

     a. Is one (pie baking versus lining up ingredients) better or worse? Why?

Appendix B: Text of Invitation Email to Potential Participants

Hi ***,

My name is Leanne Perry and I'm in the final year of my PhD program in Higher, Adult, and Lifelong Education at MSU. I was reviewing your publication on ***. As a result, I am inviting you to be a participant in my dissertation research, which focuses on factors influencing interdisciplinary research collaborations.

Purpose:

I am interviewing faculty, postdoctoral fellows, and graduate students about their experiences in interdisciplinary collaborative groups with the aim of furthering understanding about ways research collaborations are influenced by the people within them, institutional structures and functions, and external forces (e.g., funders, policies).

What is being asked of you:

If you are interested in sharing your experience with interdisciplinary work, I ask you complete this short eligibility survey (approximate time commitment: 2 minutes). Should you meet the inclusion criteria of the study, as determined by the survey, I will request about 60 minutes of your time for an in-person interview. There is a possibility I will ask you to participate in an optional follow-up interview that would last somewhere between 30-60 minutes.

This research has been approved by MSU's Institutional Research Board (IRB # x13-894e; i044488) and is being supervised by Dr. Matthew Wawrzynski, Associate Professor, Educational Administration.

I will also connect with the other members of your research team to invite them to participate. If you have any questions, please don't hesitate to get in touch.

Thank you for your consideration,
Leanne

Eligibility Survey Link: https://msucoe.qualtrics.com/SE/?SID=SV_2oaUjWnJJ7ediD3

Figure 5 Eligibility Survey

Role & Research

During your time at MSU, have you engaged in collaborative research?

○ Yes

○ No

What is your role at MSU?

○ Faculty

● Postdoctoral Fellow (Postdoc)

○ Student

○ Other

Type of Faculty Appointment

○ Fixed Term Instructor

○ Fixed Term Assistant Professor

○ Fixed Term Associate Professor

○ Fixed Term Professor

○ Health Programs Assistant Professor

○ Health Programs Associate Professor

○ Health Programs Professor

○ NSCL Engineer (any rank)

○ NSCL Physicist (any rank)

○ NSCL Professor (any rank)

○ Tenure Stream Assistant Professor

○ Tenure Stream Associate Professor

○ Tenure Stream Professor

○ Other (please specify)

Figure 5 This figure includes the eligibility survey sent to potential participants.

Figure 5 (cont'd)

Student Category

○ Doctoral/PhD

○ Master

○ Undergraduate

What is your field of study? (Please be as specific as possible e.g., "higher education administration" is more descriptive than "education")

[   ]

In which of these major categories does your field best fit?

○ Humanities

○ Professional (e.g., veterinary medicine, law)

○ Science, Technology, Engineering, & Math (STEM)

○ Social Science

○ Other
   [   ]

While engaged in collaborative research at MSU, your research group:

○ is/was comprised of people only from MSU

○ has/had at least one person from outside MSU

Is/was this research group based at MSU (e.g., Was its administrative home at MSU? Were a majority of PIs from MSU?)

○ Yes

○ No

Figure 5 (cont'd)

Which of the following best describe the area your collaborators work/worked in? (Select all that apply).

☐ Humanities

☐ Professional (e.g., veterinary medicine, law)

☐ Science, Technology, Engineering, & Math (STEM)

☐ Social Science

☐ Other

What is/was the focus of your collaborative research?

If selected for inclusion in this study, would you be willing to share an invitation to participate in this research with others in your collaborative group (i.e., faculty, postdocs, and graduate students)?

○ Yes

○ No

Your First Name

Your Last Name

How would you prefer I contact you?

○ Email

○ Phone

○ Either Email or Phone

Figure 5 (cont'd)

Preferred Email Address

Preferred Phone Number xxx-xxx-xxxx (optional)

Gender

○ Female

○ Male

○ Prefer not to disclose

○ Other

Are working/studying at MSU on a visa?

○ Yes

○ No

Where are you from?

Race

○ African American or Black

○ American Indian or Alaska Native

○ Asian

○ Hispanic or Latino/Latina

○ Native Hawaiian or Other Pacific Islander

○ Two or More Races (specification is optional)

○ White

Appendix D: MFIIRC Detailed Description

Table 5
MFIIRC Detailed Description
_____

Inputs/Antecedents
External Level: Anything external to the group (e.g., funders, institution)
- *Funding Availability*: Prompts PI(s) to apply, often a reason for the genesis of the group
- *Institutional Supports*: Interdisciplinary centers, websites to search for collaborators, research services offices, administrative support, etc.

Group Level: The collaborative group itself
- *Communication*: Interaction between members is crucial; can be mediated by technology for people who are geographically dispersed; focus on learning the language of other disciplines is important to understanding each other, progressing on the work, and integration; communication must be prioritized especially for geographically disbursed groups
- *Leadership:* Interdisciplinary projects require strong leadership to guide the team, provide vision and direction, alert the group to potential problems, mitigate issues, handle grant administration, etc.
- *Place:* people prefer in-person interaction although that's not, obviously, always possible; groups who spend time together (e.g., travel together or see each other frequently for meetings, informal interactions) report better "getting to know each other" and increased familiarity with their colleagues
- *Resources*: Teams need adequate funding, time, supplies to be effective; also need the appropriate people in the group to do the work well
- *Social/Affective Characteristics:* Getting along, developing trust, informally interacting, bonding as a group, feeling part of the team, etc.

Individual Level: Individual members of the collaborative group
- *Career Development:* anything to do with reappointment, promotion, and tenure requirements; related to policies for postdocs and/or graduate students about publication or other exit requirements (i.e., people need to do these tasks to get tenured, graduate, have their contract renewed, etc.)
- *Intrinsic Motivation:* People are interested in the work, curious about the problem domain, etc.
- *Professional Network:* Groups are often formed based on who people know rather than someone "cold-calling" someone he/she read about in the literature and inviting him/her to collaborate.

Potential Outcomes
External Level: Anything external to the group (e.g., funders, institution)
- *Advancement Toward Problem Solution*: when grants are awarded and work is conducted, generally there is some outcome that should address a particular problem or need
-

Table 5 (cont'd)

- *Revenue Generation for Institution*: Institutions take significant portions of grant dollars from investigators

Table 5 (cont'd)

Group Level: The collaborative group itself
- *Expanded research capacity*: Similar to advancing toward a problem solution, groups who progress in their research goals generate further avenues for research, build upon their prior work, and can splinter into sub-groups to investigate tangential projects

Individual Level: Individual members of the collaborative group
- *Career Development:* Reappointment, promotion, and tenure; new opportunities are presented
- *Expanded Professional Network:* Networks beget networks; collaboration can be critical for grad students, postdocs, and new faculty who are not yet established in a research community
- *Experience with Collaboration:* Learning how to work interdisciplinarity is challenging so the more one practices, the better he/she can become in navigating the process.
- Skill Development: Working across disciplines helps people understand other disciplines, which can increase the number of people one's able to communicate with/work with professionally; people can learn new and/or refine existing skills

Note. Table 5 provides a detailed description of each MFIIRC factor illustrated in Figure 4.

Appendix E: Summary Table of Findings

Table 6

Summary of Findings

Finding	Discussion of Finding Within the Literature	Participant &/or Case	Demonstrative Quote
External Attention	Baldwin & Austin, 1995; Pavangadkar, 2012; Rhoten, 2004; Farrell et al., 2011; Perry et al., 2012	All cases	[Our] "funder really cares about deliverables" The work is "really cutting edge stuff." The group is challenged because although the research is innovative and exploratory, the funder still expects an applied deliverable, which limits the scope of what the group can undertake (Dr. Sam Loomis, Case Two).
Intrinsic Motivation	Fox & Faver, 1984; Rhoten, 2004, Sloan, 1989; Farrell et al., 2011; Perry et al., 2012	All cases	[The group's research focus] is pretty [disturbing] and [we're] trying to shed some light on that mystery. That is kind of why I got into the field I'm in (Laurie Stroud, Case Two).
Systemic Implementation	Farrell et al., 2011; Perry et al., 2012; Rhoten, 2004	All cases	It seems to be coming from everywhere above – the provost, multiple deans, chairs – that [interdisciplinary research] is what the institution is really investing in. They've created new positions and created new offices to try and facilitate this. They've been on target with their message (Dr. Maude Lebowski, Case Three).

Table 6 (cont'd)

Assessing & Supporting Faculty Work	Farrell et al., 2011; Hurtado & Sharkness, 2008; Lattuca 2001; Moody, 2004; Perry et al., 2012; Rhoten, 2004; Trower, 2008	All cases	My sense is that for going from associate to full it would be acceptable for me to get an individual research grant but that everybody would recognize it as more significant to get an interdisciplinary grant that was bringing in big overhead to the university. That's what we're being told we're supposed to do. So my understanding of the criteria for tenure and promotion has been that grant getting is extremely important, highly valued, and that you're dead in the water without it (Dr. Maude Lebowski, Case Three).
Communication & Information Technology	Campbell, 2005; Crowley, Eigenbrode, O'Rourke, & Wulfhorst, 2013; Cummings & Kiesler, 2008; Farrell et al., 2011; Kozlowski & Ilgen, 2006; NAS, 2005; Nash, 2008; Perry et al., 2012; Schmidt et al., 2012	All cases	In the beginning it was everyone was speaking a different language. It was really frustrating and I kind of felt like somehow I became the translator between all these different fields (Laurie Stroud, Case Two).
Organizational Values & Identity	Bennett & Gadlin, 2013; Farrell et al., 2011; Perry et al., 2012	All cases	I feel really good. I think we all have complementary skill sets and I think they all do impressive work so I feel really good aligning myself with them. I feel like we're kind of a little research team that has formed some bonds so far. We've bonded (Dr. Jeffrey Züppe, Case Three).

Table 6 (cont'd)

Professional Development Opportunities	Farrell et al., 2011; Perry et al., 2012	All cases	Ten years ago I knew nothing about [field related to his own]. So now I know much more about [related field] and I know how much everything is connected. So, in any area you really need to do collaborations between different fields to truly understand what's going on (Dr. Walter Sobchak, Case Three).
Professional Networking Opportunities	Clark, 2009; Farrell et al., 2011; Melin, 2000; Perry et al., 2012; Salter & Martin, 2001	All cases	I've found that fascinating to collaborate with others. In my own case it's actually helped me because I found more channels to do research than my original research. Now actually it's expanded my view and my research into many other areas (Dr. Walter Sobchak, Case Three).
Disciplinary Boundaries	Caruso & Rhoten, 2001; Rhoten, 2004; Schmidt et al., 2012	Cases One & Three	So in <Dr. Lebowski's field>, for instance, if you want to publish a paper it takes a year and a half. It's a terrible long time compared to what we're <natural science> talking about so we'll sit down to a meeting and talk about the first pubs we can get out in year one. Dr. Lebowski says we'll be talking about year two or three [before anything could hit publication in that field's journals]. So the pace is different (Dr. Donny Kerabatsos, Case Three).

Table 6 (cont'd)

Funding & Resources	Rhoten, 2003; Rhoten, 2004	Case One	Different people draw different salaries. Krantz only gets 5% of his salary from it [the grant]. But for example Morgan [Davis] gets more in summer salary from the grant than I do because her salary is so much higher. She gets one month of $120,000 and I get one month of $65,000 and it just works out to different amounts. So in some ways she gets paid a lot by the grant and Gunadi and I haven't been thrilled with how much she's contributed to the grant. So that's kind of a little source of conflict that exists (Dr. David Webb, Case One).
Leadership	Felps, Mitchell, & Byington, 2006; Holley, 2009	Case One	I don't know if we had a conversation between the two of us about how we would share grad students or whatever. I think we had such a relationship that we weren't concerned about how we divvy that [resources and graduate students] up just that we would have come to an understanding and I think it's just been that way (Dr. Susilo Gunadi, Case One).
Place	Cummings & Kiesler, 2008; Nash, 2008; Rhoten, 2004; Rhoten 2003	All Cases	I came away from that trip with a much better sense of how the pieces were going to fit together and to some degree, reshaped my understanding of my piece so it would work better with the other pieces. I think we came away from that [trip] feeling more like a team although (Dr. Maude Lebowski, Case Three).

Table 6 (cont'd)

Project Administration	NSF, 2010	Cases One & Three	I think that the limitations or the constraints of my particular project are less due to interdisciplinary problems than they are just basic kinds of administrative logistic kinds of problems (Dr. Susilo Gunadi, Case One).
Organizational Politics	Cropanzano & Mitchell (2005).	Case One	The actual politics within the university I hadn't taken into account. People have gotten involved and left the project and changed their level of collaboration with me because of those things and I've kind of learned to take that into account and to adapt to it when it does happen so that it doesn't impact the project (John Degen, Case One).
Muddling Through	Barrick, 2012 in Pavangadkar, 2012; Kerr, 2012 in Pavangadkar, 2012	All Cases	I guess for me, I liked it [muddling]. I felt like it was good – like it helped you not only understand the process but it helped to interact with that person and see not just how the process works but how their thought process works. It built the relationship because you're sitting next to them and asking them questions and kind of feeling your way through it with them (Mike Myers, Case Two).

Table 6 (cont'd)

Networks	Clark, 2009; Farrell et al., 2011; Melin, 2000; Perry et al., 2012; Salter & Martin, 2001	All Cases	[If] I have a specific need and if there's no one in my immediate network to fill that need, I'm motivated to implement the vision that I see, as I see it. So if I recognize a need for a certain skill set then I will try to secure that skill set from my local network first, my extended network and then, if I still haven't found someone I'll call people out of the blue or email and set up a call –I'm interested in making the project happen the way I see it. I'll do my best to hit that mark and if I can't then I'll start making concessions (Dr. Jeffrey Züppe, Case Three).
Integration	Amey & Brown, 2004; Pavangadkar, 2012	All Cases	I feel like already there's something that's bigger than the sum of its parts (Dr. Maude Lebowski, Case Three).

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