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Collaborative Development of an Interdisciplinary Scientific Research Proposal: Negotiation through Boundary Objects

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**COLLABORATIVE DEVELOPMENT OF AN INTERDISCIPLINARY SCIENTIFIC
RESEARCH PROPOSAL: NEGOTIATION THROUGH BOUNDARY OBJECTS**

by

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ABSTRACT

COLLABORATIVE DEVELOPMENT OF AN INTERDISCIPLINARY SCIENTIFIC RESEARCH PROPOSAL: NEGOTIATION THROUGH BOUNDARY OBJECTS

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Old Dominion University, 2016
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Funding agencies are increasingly soliciting proposals that require interdisciplinary and collaborative solutions for a scientific issue. The development of these research proposals is challenging and often problematic due to the complexity involved in integrating the differing characteristics of multiple disciplines to produce a single, cohesive document. Minimal research has been conducted to examine this collaborative process as it occurs. This study uses the concept of boundary objects as a framework to analyze an interdisciplinary and collaborative team during the development of a research proposal. Multiple methods were used to identify disciplinary differences and analyze their negotiations. This study delineated disciplinary differences and highlighted the need for increased disciplinary awareness to improve the collaborative process. The findings also suggested that funding agencies need to modify solicitation and review processes to accommodate interdisciplinary proposals.

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This dissertation is dedicated to two very important men in my life. First, my husband, who was an unwavering source of support and through the writing of this dissertation, did not let my children starve. Next, my father, who started me on this journey and always knew I could pull it off.

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CHAPTER 1

INTRODUCTION

The purpose of this study is to examine the complex process that is required for the development of interdisciplinary and collaborative research proposals in the sciences. Funding agencies are increasingly requesting interdisciplinary solutions to scientific issues, prompting a rise in the number of collaborative teams that cross disciplinary borders. This scenario complicates the collaborative process by requiring the integration of disciplinary differences to produce a cohesive proposal and research design. Funding agencies also face challenges in determining how to effectively solicit these research solutions and review subsequent proposals. When combined, these challenges can result in an inefficient funding system that requires significant effort from all people involved and minimal reward as reflected by low funding rates. Additional research is therefore necessary to understand the complexities of this process in order to potentially improve components of the system. This study addresses this need through the analysis of an interdisciplinary and collaborative team and their process of proposal development. The following dissertation describes this analysis and the insight it offers.

1.1 BACKGROUND

Research proposals are an essential component of scientific progress in the United States. Scientific research is extremely expensive and therefore requires adequate funding for execution. According to the latest analyses, academic institutions expended approximately \$63.1 billion in 2011 on research and development (R&D) activities in science and engineering. Federal sources provided \$38.7 billion (61%) to this R&D, with an additional \$16.3 billion (26%) provided by

state and local governments or academic institutions. External federal funding for industry R&D is also significant as demonstrated by the contribution of \$31.3 billion to these efforts in 2011 (National Science Board, 2014). These agencies and institutions provide over 85% of academic and 11% of industry R&D funding. They are therefore a primary source of money for scientific research in the United States.

A significant amount of research funding from federal agencies, local governments, foundations, and institutions is awarded through a competitive process. For example, more than 80% of funding from the National Institutes of Health (NIH) is awarded through competitive proposals (National Institutes of Health, 2015). Therefore, research proposals are critical to the funding process and act as a primary mode of communication between researchers and funders. Since persuasive proposals are necessary to acquire funds and in turn, conduct research, scientists invest a substantial amount of time and energy into developing these complex documents.

Although funding exists, the federal budget cannot satisfy the extreme monetary demand for scientific R&D (Howard & Laird, 2013). Therefore, the competition for these limited funds is fierce. This leaves scientists with the challenge of understanding agency needs and writing highly persuasive proposals that are more relevant and innovative than their competition. These proposals are received by the requesting agency, which then selects reviewers to evaluate each submission and decide if funding is recommended. The challenges associated with developing a relevant and competitive proposal have been recently exacerbated by the rise in agency requests for interdisciplinary collaboration. This situation adds complexity to both the collaborative and funding processes, leading to more issues that can result in wasted effort and an inefficient funding system.

The demand for collaborative and interdisciplinary research is increasing in scientific fields. This is due, in part, to the commonly held belief that interdisciplinary collaborations lead to greater innovation and knowledge creation (Adler & Heckscher, 2006) as well as the ability to address increasingly complex issues not possible by a single person or discipline (Sonnenwald, 2007). Numerous funding agencies have latched onto these perceived benefits of interdisciplinary collaboration and are requiring the involvement of multiple disciplines per research endeavor in order to qualify for funding (Clark & Llorens, 2012). This trend is demonstrated by the NIH and their implementation of Multiple Principal Investigator (MPI) awards in 2006 to stimulate interdisciplinary research. The NIH granted three of these awards in 2006 and by 2013, MPI awards accounted for approximately 20 percent of all major funded proposals (Stipelman et al., 2014).

The surge in interdisciplinary proposals and research will not end in the near future. This approach therefore requires additional attention because it significantly impacts the disciplinary and normalized practices of scientists and agencies. Researchers must now write a perfectly tailored and cohesive proposal with a variety of people who embody different and often competing personalities, priorities, requirements, and knowledge. This process is complex and labor intensive, requiring each collaborator to translate, debate, simplify, and negotiate his or her identity with those of others (Star & Griesemer, 1989). The collaborators must also effectively negotiate their understanding and interpretation of the agency priorities and review criteria to develop a persuasive proposal. The negotiation and strategic integration of disciplinary knowledge can result in the production of a significant and innovative research proposal that appeals to agency needs. However, the challenging nature of this process often leads to limited success and even if submission occurs, a poor funding outcome. This limited funding rate

translates into wasted effort, lost money, and no research for the involved collaborators.

Therefore, researchers need to approach and practice interdisciplinary and collaborative proposal development in an informed manner in order to maximize return on investment (Stokols, Misra, Moser, Hall, & Taylor, 2008).

Agencies are also impacted by their interdisciplinary requests and must modify their practices to accommodate this approach. Funders need to understand the collaborative process and the complexity of interdisciplinary research in order to make appropriate requests for and reviews of proposals. The realized need for these changes in practice has only recently occurred. In order to identify and implement these changes, an improved understanding of the basic interdisciplinary and collaborative process is necessary.

Research concerning interdisciplinary collaborations in the sciences has increased over the last decade. These studies have examined specific collaborations and have suggested potential sources for failed productivity. These sources include differences in personality, geographical location, institutional practices, and disciplinary character, just to name a few (Lowe & Phillipson, 2009; Morse, Nielsen-Pincus, Force, & Wulfhorst, 2007). Scholars have often focused on how differing institutional requirements and challenges associated with communicating across geographical distance affect collaborative outcomes (Evans & Marvin, 2006; Lowe & Phillipson, 2009). Although this research exists, there are many areas that require further examination. Surprisingly, limited work has been done to identify specific disciplinary factors that impact an interdisciplinary collaboration within the sciences (Lele & Norgaard, 2005; Morse et al., 2007). This may be due to the assumption that the differences that do exist are nominal or common knowledge, making specific identification unnecessary. Or, as one scholar suggested, identifying specific differences between disciplines is not possible due to the

difficulty associated with defining the term “discipline” (Lele & Norgaard, 2005). Either way, this gap in knowledge is significant because the defining characteristics of an interdisciplinary team are disciplinary differences.

Beyond this gap in knowledge, recent literature on interdisciplinary collaborations tends to focus on identifying barriers to success and designing strategies to enhance instances of agreement in order to increase productivity. These studies are limited by their focus on barriers and outcomes as opposed to analyzing the process that occurs during a successful collaborative effort (Cooke & Hilton, 2015). Nancy Cooke, a professor of human systems engineering, and Margaret Hilton, a senior program officer at the National Research Council (NRC), conducted a review of the current research on collaborative teams in the sciences to inform the emerging field of The Science of Team Science. These researchers emphasized that “there is a clear need for further and more sophisticated research on how the multiple individual characteristics of the team or group members combine within science teams and groups, and how these interactions and processes are related to effectiveness” (Cooke & Hilton, 2015, p. 219). In addition, due to the infancy of this research area, few effective methodologies have been identified and validated to analyze this process. Finally, no research, to my knowledge, has been conducted on the proposal development process with respect to an interdisciplinary and collaborative team of scientists.

Additional research is necessary to address these gaps in knowledge, particularly due to the importance of research proposals in the funding process and the complicating challenges associated with working in a collaborative and interdisciplinary team. This study offers insight into this scenario, informing both researchers and funding agencies. This understanding may improve a researcher’s ability to effectively participate in an interdisciplinary collaboration and

contribute to the production of a cohesive proposal. Funding agencies may benefit as well, using this insight to more accurately request and appropriately review an interdisciplinary research solution.

1.2 RESEARCH AIMS

The gaps in knowledge described above demonstrate the need for this study and raise a variety of important questions. First, what are the specific differences between scientific disciplines that may be a source for collaborative complications? Second, what process does a collaborative team undergo to reconcile disciplinary differences in order to develop a cohesive research proposal? Finally, what factors make this process successful and what does the term “success” mean for proposal development versus agency review?

In the following study, I address these questions through the application of a novel methodology. Specifically, I use the concept of boundary objects as a methodological tool to examine the process of negotiation between members of an interdisciplinary collaboration as they design the project description for a research proposal. Boundary objects are items such as texts, machines, or software systems that are used by different social groups or disciplines. These objects have a robust structure, function, and informational capacity that is accepted and recognized by each of these disciplines; and, in turn, these objects can be adapted according to disciplinary need. These qualities allow boundary objects to act as modes for negotiation between disciplines, allowing each collaborating party to maintain disciplinary identity (Schryer, Afros, Mian, Spafford, & Lingard, 2009; Star & Griesemer, 1989). A boundary object is therefore a nexus of collaborative activity and can be used as an effective tool for identifying specific factors that require negotiation and resolution. In addition, this concept effectively

frames the examination of how these factors are productively and successfully negotiated into a final product. Using the boundary object concept, my study addresses the following aims:

- Aim 1: Identify the essential boundary objects used by a scientific interdisciplinary collaborative team in the development of a research proposal.
- Aim 2: Identify and describe the informational requirements of the primary essential boundary object and the social worlds that it intersects.
- Aim 3: Examine the primary essential boundary object to determine what and how factors are negotiated between the members of the scientific interdisciplinary collaborative team in order to develop the research proposal.
- Aim 4: a) Determine if the negotiations conducted through the primary essential boundary object were successful in producing a rhetorical document; b) Determine if the negotiations conducted through the primary essential boundary object were successful in persuading an award of funding.

To achieve these aims, my study uses multiple methods that are primarily qualitative in form. The findings from my study enhance our understanding of how interdisciplinary collaborations in the sciences function and produce a cohesive research proposal. This insight can inform collaborators and agencies by demonstrating the intricacies of the interdisciplinary and collaborative process and by suggesting areas for improvement throughout the funding system.

1.3 CHAPTER OVERVIEW

This dissertation represents my research and conclusions concerning the process of proposal development by an interdisciplinary, collaborative, and scientific team. The

dissertation is organized into seven chapters. Following my introductory chapter, I review the current literature to demonstrate the need for my research and the theoretical frameworks used to support the methods, analyses, and conclusions of the study. This discussion begins by defining the term “discipline” and describing the structures and functions of these scientific communities. The ensuing discussion of interdisciplinarity introduces complexity into the collaborative process, particularly with respect to the development of scientific proposals. I then discuss and justify the theoretical foundation of my study by describing the concept of boundary objects (Star and Griesemer) and aspects of genre theory. This literature review sets the stage for all remaining chapters.

In Chapter 3, I provide a detailed description of the multiple methods used to address the study aims, as well as the requirements for participant recruitment. The qualitative methods described here include an interview protocol, demographic analysis, meeting observations, email and track-changes protocol and textual analysis. These methods are uniquely integrated to support four separate analyses including the identification of boundary objects, the description of the social worlds that intersect the object, examination of the informational requirements of the object, and the analysis of negotiations through the object. Subsequent chapters discuss additional analyses that were dependent on emerging findings.

Chapter 4 is the first analytical chapter of the dissertation. Within the first few sections, I discuss the study qualifications for the research and introduce the proposal. This study examines a research proposal developed in response to a solicitation from the National Science Foundation’s (NSF) Ecology and Evolution of Infectious Disease (EEID) Program. This chapter provides participant profiles for the individuals who were involved in the interdisciplinary and collaborative development of this proposal. Following this discussion, I analyze interview,

meeting, and email data to identify potential boundary objects that are essential to proposal development for the team under study (Aim 1). Using this data, I also identify the primary object of interest that becomes the focus of the remainder of the study. Additional analyses of interview and demographic data demonstrate that the object of interest involves multiple social worlds and in part, qualifies as a boundary object (Aim 2). More importantly however, through the development of detailed descriptions for each discipline involved in the study, I reveal a distinct set of characteristics that differ between each scientific discipline. These disciplinary factors can complicate collaborations and force negotiation.

Chapter 5 addresses Aim 2 by using a framework based on genre theory and the concept of genre ecology. This framework is used to analyze and discuss the common and plastic informational requirements of the primary boundary object of interest, the EEID proposal. Analysis of informational requirements further characterizes the boundary object and reveals that the plastic elements are the actual sites where collaborators negotiate their disciplinary differences. This analysis also offers a detailed description of the proposal topic, content, and rhetorical structures used to produce a cohesive research plan that focuses on tick-borne infectious disease. Finally, this chapter addresses the complexity of the proposal's context through the development of a genre ecology.

Chapter 6 builds upon previous findings to address Aims 3 and 4 by identifying specific disciplinary factors that are negotiated through the boundary object. In addition, the chapter provides a detailed analysis of how these negotiations take place between collaborators and within a greater system. The outcomes of these negotiations are also examined, which suggests how negotiations may be successful in producing a cohesive proposal but not in the award of funding.

The final chapter of the dissertation presents the major analytical findings from the study and places them into a greater context. I discuss how an increased awareness of disciplinary differences may impact the collaborative process, and how my findings inform agency solicitation and review practices. My findings have applications in additional fields, which are also discussed. I finish the chapter with a description of possible directions for future research.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of the literature that informs my study. As introduced in Chapter 1, the interdisciplinary and collaborative development of a research proposal is exceedingly complex. To gain an appreciation for this complexity and the challenges associated with this process, this chapter first establishes the meaning and importance of scientific disciplines. The definition of interdisciplinarity, its benefits, and challenges adds to this appreciation and highlights the need for additional research into the process of proposal development. To address this need, I introduce the concept of boundary objects as a foundation for this study. Genre theory is also discussed in how it is complicated by and also informs the process of proposal development by an interdisciplinary and collaborative team.

2.1 SCIENTIFIC DISCIPLINES

To the outside observer, disciplines that are categorized under the term of science may initially appear homogenous with subtle and insignificant differences between the fields. In reality however, each scientific discipline is unique and differs from others in history, domain of study, values, methodologies, and other characteristics. These differences can be the source of conflict or confusion when two or more scientific disciplines choose to collaborate on a single endeavor. However, before we can begin to make sense of interdisciplinary and collaborative interactions, we must understand what it means to be a scientific discipline.

The examination of the semantic history of the term discipline is worthy of a dissertation length work. However, for our purposes, the term discipline was initially associated with the

deliberate organization of knowledge for pedagogical purposes and acted as a space to archive knowledge that had been accumulated (Krishnan, 2009; Stichweh, 2003). In addition, the term discipline implied punishment for or correction of mistakes, thus defining ways of thinking and acting in a specific group (Foucault, 1979; Krishnan, 2009; Stichweh, 2003). During the nineteenth century, societal change, increased communication via print, exploration, and economic growth all contributed to an increase in the breadth of scientific inquiry and the accumulation of knowledge in Europe. This prompted scientists, particularly in the German university system, to specialize their topics of study and simultaneously, their professional roles. Hierarchical communities developed around these specialized lines of scientific inquiry both within and among universities in the competitive pursuit of knowledge and career advancement. Thus, the modern form of scientific disciplines as complex communication and knowledge production systems started to develop (Stichweh, 2003).

Scholars present a variety of criteria to define the more modern term of discipline. Julie Thompson Klein is a scholar who has dedicated much of her career to the examination of disciplinarity and interdisciplinarity. She states that a discipline is “the specialized exploration of particular objects and subjects using particular methods, concepts, tools and exempla in addition to laws and theories which account coherently for the objects and subjects under study” (Klein, 1983, p. 35). In later work, Klein (2006) expands this definition stating that a discipline has specific “traits that produce a distinct worldview or discourse” to include specialized bodies of evidence, canons, paradigms, concepts, skills, language, argument styles, and epistemologies (p. 10). This specialized exploration that Klein speaks of does not hold significance in society and cannot contribute to achievements in knowledge production without a community of individuals sharing a similar pursuit. Thus, scientific disciplines can be further defined as

communities of individuals who have intense or frequent interactions and share expertise, values, and goals (Kuhn, 1996; Stichweh, 2003). These scientific disciplines are maintained and grow over time through specific learning and indoctrination methods that enable newcomers to join the community (Krishnan, 2009).

Lave and Wenger's concept of communities of practice can further describe and provide insight into scientific disciplines and the numerous differences that emerge between them (Lave & Wenger, 1991; Wenger, 2006). Wenger (2006) defines communities of practice as "groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (p. 1). These groups must meet three criteria to be considered a community of practice. First, the group must have a shared domain of interest that defines its identity. Participation in the group implies that each member has a certain competence and investment that contributes to this domain. Each scientific discipline involves multiple participants who focus their work in a specific domain of interest. These domains vary significantly between disciplines, from physics, to ecology, to chemistry, and so on. The second criterion requires the group to be a community that interacts, shares information, and develops relationships on some level. This enables members to learn from one another to formalize the domain of study. Members of scientific disciplines interact constantly through daily research, reading manuscripts, attending conferences, and more. These scientists learn about their peers' latest techniques and findings, and in turn, refine this knowledge to gain a greater understanding of their specific fields.

The final qualifier to be a community of practice requires the group to participate in a shared practice by using community resources (Wenger, 2006). One significant practice in scientific disciplines is the development and performance of experimental methodologies.

Methods are tailored to the domain of study and are perfected through repeated use within the community. Methods can differ between disciplines in a variety of ways. For instance, multiple fields can use the same methodology to acquire different data, multiple fields can use different methods to address a single issue, and each field can develop highly specialized methods that are used only within the field. To illustrate this point, multiple scientific disciplines use the real-time Polymerase Chain Reaction (PCR) experimental protocol to address different aims. From this single method, a virologist can identify a virus to provide a clinical diagnosis and monitor viral load in response to therapy. In contrast, a forensic scientist can use PCR to amplify and analyze DNA samples from a crime scene to identify a guilty party. Different fields can use unique perspectives and methods to address a similar issue, such as examining situational stress and memory development. A psychologist may use observation and interview techniques to determine that increased stress leads to enhanced memory development and retention. An endocrinologist or neuroscientist may use different approaches by measuring stress hormone levels and imaging neural activity to draw the same conclusion. These examples demonstrate the significant differences between scientific fields, particularly in relation to the experimental approach and practice of methodology.

The preceding concept suggests that each scientific discipline qualifies and can be defined as a community of practice. Each discipline has a unique identity, practices, and specific membership requirements. A natural outcome of the formalization of a scientific discipline is the emergence of differences and the development of boundaries between fields. Over time, the community develops unique methodologies as discussed above, in addition to increasingly specialized language, values, pedagogy, knowledge, and perceptions of reality based on how the group engages the topic of study (Becher & Trowler, 2001; Brammer, Amare, & Sydow, 2008;

Krishnan, 2009). These specialized identities result in the formation of boundaries between scientific disciplines and are actively maintained for a variety of reasons, only a few of which are discussed here. Scientific disciplines are an important construct in that multiple individuals share interest in a common topic, thus enabling sustained inquiry by providing a context and significance to the topic. In turn, disciplines enable a subject of research to be examined multiple times by multiple people, providing opportunity for modification and debate of methods and findings. The discipline becomes disciplined. These structures therefore enable efficient knowledge production through access to established methodologies, credible source knowledge, and a disciplined way of thinking. The resulting scientific claims have enhanced credibility through disciplinary rigor of inquiry (Bridges, 2006). Scientific disciplines also serve as a common and currently effective method of organizing knowledge for pedagogical purposes (Bird, 2001; Bridges, 2006; Krishnan, 2009). Finally, scientists often depend on their disciplines for professional stature and compensation. The preservation of one's discipline is therefore necessary to ensure professional survival, advancement, and prestige (Krishnan, 2009).

The benefits of possessing a disciplinary identity in today's research and academic environments cause scientists to fiercely protect their disciplines and foster boundaries between competing fields. However, no matter how hard a community tries to maintain a specific identity, disciplines are plastic and develop, vanish, or divide in response to the fluid and unstructured nature of science and society (Bridges, 2006). Even with this fluidity and frequent changes in perceived boundaries, disciplinary rules and structure can be too restrictive to scientific inquiry. Thus, scientists are increasingly crossing disciplinary boundaries, developing heterogeneous identities, and participating in interdisciplinary collaborations in the pursuit of scientific knowledge.

2.2 BENEFITS AND CHALLENGES OF INTERDISCIPLINARITY

The definition of interdisciplinary is debatable and the term is often interchanged with multidisciplinary and transdisciplinary. William Newell, a professor of interdisciplinary studies at Miami University, suggests that, “unlike disciplines, interdisciplinary studies as we now understand it is characterized not by a particular subject matter, but rather by its distinctive approach or process, which both embraces and transcends the disciplines” (Newell, 2013, p. 31). For the sake of this study, an interdisciplinary collaboration is the process by which two or more sets of disciplinary knowledge and customs are coordinated or integrated to address a single problem and to create new knowledge that impacts all disciplines involved (Friman, 2010; Klein, 2006; Morse et al., 2007; Sonnenwald, 2007).

This definition of interdisciplinary differs from that of multidisciplinary and transdisciplinary. A team of Canadian researchers, in the field of public health, defined these terms as they relate to health education, research, services, and policy. Bernard Choi and Anita Pak (2007) discussed the issues associated with the increasing frequency and interchangeable use of the terms interdisciplinary, multidisciplinary, and transdisciplinary in scientific literature. These authors sought to define these terms to clarify their meaning to the health fields and to differentiate between the varied types of collaborative work. To do this, Choi and Pak (2007) surveyed dictionaries, websites, and medical and scientific literature for existing definitions of these terms. The authors confirmed their varied use, grouped their common and prominent characteristics, and subsequently developed the following definitions:

We conclude that the three terms are used by many authors to refer to the involvement of multiple disciplines to varying degrees on the same continuum. Multidisciplinary, being the most basic level of involvement, refers to different (hence “multi”) disciplines that are working on a problem in parallel or sequentially, and without challenging their disciplinary boundaries. Interdisciplinary brings about the reciprocal interaction between (hence “inter”) disciplines, necessitating a blurring of disciplinary boundaries, in order to

generate new common methodologies, perspectives, knowledge, or even new disciplines. Transdisciplinary involves scientists from different disciplines as well as nonscientists and other stakeholders and, through role release and role expansion, transcends (hence “trans”) the disciplinary boundaries to look at the dynamics of whole systems in a holistic way. (Choi & Pak, 2006, p. 359)

The following study focuses on interdisciplinary collaborations as opposed to other types of interaction in order to gain insight into how disciplinary borders are maintained, crossed, and blurred to create a single cohesive product.

Interdisciplinary and collaborative work in the sciences is primarily driven by the pursuit for the production of innovative knowledge. A disciplinary approach to research can be limiting. William Newell has examined the interdisciplinary process, its benefits, and challenges. Newell (2001) suggests that disciplines may be too specialized in their knowledge banks to effectively address the breadth and complexity of specific scientific issues. Armin Krishnan (2009), a professor of security studies, further explains this issue:

The prevalent tendency in most disciplines of increasingly narrow and deep specialization would make research less relevant to outsiders or society, would foster insularity and imperialism rooted in partial and ideological thinking, would hinder the exchange of ideas across disciplines and would ultimately impede the progress of science. (p. 4)

Newell suggests that interdisciplinarity is a natural response to and solution for the increasing specialization of disciplinary inquiry (Newell, 2013). Therefore, an interdisciplinary collaboration is highly beneficial because it can enhance scientific progress by examining issues that are increasingly complex and more broad in scope than those studied by single disciplines (Sonnenwald, 2007).

The interdisciplinary process is also beneficial by increasing the opportunity for innovation. The integration of knowledge from different disciplines may elicit new forms of problem solving and provide different perspectives in the analysis of collected data, thus leading

to novel knowledge creation (Adler & Heckscher, 2006; Hardy, Lawrence, & Grant, 2005; Sonnenwald, 2007). To support this idea, Wuchty, Jones, and Uzzi (2007) conducted a study to determine if teams produced better science compared to individuals. These authors analyzed 19.9 million research articles and 2.1 million patents to determine team makeup and the citations each paper received. Wuchty et al. (2007) determined that the collaborative production of scientific publications has substantially increased over the past few decades. In addition, these papers were more highly cited compared to those produced by an individual. These findings suggest that team science is the dominant trend, has greater impact, and produces more novel findings (Wuchty, Jones, & Uzzi, 2007). Finally, interdisciplinary publications reach a varied audience, resulting in a broader dissemination of findings that, in theory, can lead to enhanced progress (Vogel et al., 2014).

Numerous academic institutions, funding agencies, and other organizations have grasped onto the perceived benefits of interdisciplinary and collaborative research in the sciences (Clark & Llorens, 2012; Hardy et al., 2005; Rhoten, 2004). As a result, these organizations push scientists to increasingly conduct research as an interdisciplinary and collaborative team. Funding agencies, in particular, have embraced this movement and have created programs dedicated to the solicitation of interdisciplinary research. For instance, the National Science Foundation (NSF) (2015) states on their website that “promoting and funding interdisciplinary research is a high priority for the Foundation.” In addition, the NSF website relays,

Some programs are specifically restricted to interdisciplinary research topics; in those programs, a great deal of weight is given to “interdisciplinary” aspects. Some other NSF programs, while not so restricted, explicitly encourage interdisciplinary research and consider it as a positive factor. (National Science Foundation, 2015a)

Other agencies, including the National Institutes for Health (NIH) and Department of Defense (DoD), have similar initiatives, preferences and programs. This federal push for interdisciplinary

and collaborative research is seen as an attempt to gain a better return on agency investment, as discussed by Benjamin Clark and Jared Llorens:

In many respects, governmental funding policies designed to foster research collaboration can be viewed as a form of ‘human capital investment’ whereby collaborative research efforts are intended to directly raise overall levels of scientific knowledge (i.e., human capital) and contribute to greater research productivity and scientific advancement. (Clark & Llorens, 2012, p. 699)

In response to these agency demands, researchers are forced to increasingly participate in interdisciplinary collaborations in order to acquire research funding.

Unfortunately, the process of interdisciplinary collaboration is far from simple and requires a series of complex interactions. Susan Star, a sociologist, and James Griesemer, a philosopher, examined the challenges associated with mixing social worlds, such as disciplines. Star and Griesemer (1989) explain that scientists each come from different social worlds and,

when the worlds of these actors intersect a difficulty appears. The creation of new scientific knowledge depends on communication as well as creating new findings. But because these new objects and methods mean different things in different worlds, actors are faced with the task of reconciling these meanings if they wish to cooperate... Scientists and other actors contributing to science translate, negotiate, debate, triangulate and simplify in order to work together. (p. 388)

Thus, interdisciplinary collaborations in the sciences can be extremely challenging due to the necessity to resolve a variety of differences that exist between each collaborator in order to produce a single, cohesive product (Cooke & Hilton, 2015). This negotiation process requires additional time, increased effort, and a willingness to compromise compared to a single disciplinary effort. The additional work required to address differences within a collaboration acts as a barrier that often results in failed productivity and negates the potential benefits of this ever-increasing trend.

Numerous scholars, including an expert committee within the National Research Council, have suggested a variety of team features that may pose challenges to the interdisciplinary and

collaborative process. These features include an increased diversity of membership, large size, goal misalignment, geographic dispersion, varied institutional constraints, personality and managerial differences, and disciplinary knowledge integration. These factors require careful consideration and attention because they can act as sources for negotiation, potential conflict and failed productivity (Cooke & Hilton, 2015, p. 25; Jonathon N. Cummings & Kiesler, 2008; Lowe & Phillipson, 2009; Stokols et al., 2008). Although these challenges have been presented and many have been studied, limited research has been conducted to identify specific disciplinary differences that impact the scientific collaborative process. Existing literature tends to generalize the differences under broad categories such as paradigms, methodologies, values, language, work styles and research aims (Cooke & Hilton, 2015; Lele & Norgaard, 2005; Lowry, Curtis, & Lowry, 2004; Morse et al., 2007; Vogel et al., 2014). Two separate research teams led by Wayne Morse, a researcher in environmental policy, and Amanda Vogel, a health policy and management expert, conducted research on scientific collaborations involving multiple disciplines. These studies represent the little research performed to specifically identify the disciplinary factors that differ between collaborators and how they either impede or assist in the collaborative process.

Morse et al. (2007) conducted a case study on an interdisciplinary research program for graduate students in the field of biodiversity and sustainability. Students representing different scientific fields were broken into groups and required to jointly define research questions, create experimental designs integrating theory and practical problem solving, carry out the research, and co-author a paper. Morse et al. (2007) observed a variety of bridges and barriers to interdisciplinary research at the individual, discipline, and programmatic levels. Specific

disciplinary barriers that caused confusion included differences in language, paradigms, metrics, and audiences (Morse et al., 2007).

Vogel et al. (2014) offer additional insight into disciplinary differences that impact collaboration. This team conducted 31 semi-structured interviews with individuals in multiple professional roles that required cross-disciplinary work, including research center directors, principal investigators, and training directors. A coding analysis of the interviews revealed that participants believed that differences in disciplinary values, terminology, and work styles impacted the success of collaborations (Vogel et al., 2014). Vogel et al. (2014) elaborated on their findings:

These differences could lead to misunderstandings or conflicts. Participants described how these discipline-based differences often were not well understood before embarking on a TD [transdisciplinary] research collaboration and that only through collaboration with colleagues from other disciplines' and experiencing the resulting challenges – did they come to recognize, understand, and address these differences. (p. 7)

Although the interviewees identified these disciplinary factors as challenges, Vogel and her team did not observe collaborations to determine the actual impact of each factor. The studies presented by Morse et al. (2007) and Vogel et al. (2014) are important initial steps in identifying the disciplinary differences that may impact the collaborative process.

This minimal research in identifying specific differences between scientific disciplines and their impacts on collaborations stems not only from the challenges associated with defining these fluid constructs (Lele & Norgaard, 2005), but also from ingrained assumptions held about the scientific community as a whole. Due to the common study of natural phenomena, many individuals think that most scientific disciplines are highly similar and work conducted between them may not qualify as interdisciplinary. This assumption is demonstrated in a paper by Robert Evans and Simon Marvin (2006), describing their study of an interdisciplinary endeavor between

United Kingdom (UK) research councils and social organizations. These authors explain their understanding of interdisciplinary work in the sciences:

Scientists within disciplines are operating within shared paradigms or frameworks that give meaning to their work and provide a wide-ranging set of methods and norms that can be drawn on in order to make judgments about research questions and problems. Doing interdisciplinary research means working with others who may not share these assumptions and who would prefer to conduct their research in a different way. Within research councils these differences are often relatively minor, so that a set of disciplinary paradigms can coexist as variations around a set of core ideas or principles that give the research councils their distinctive identities and shape the research programmes outlined above. (Evans & Marvin, 2006, p. 1025)

There are seven UK research councils and five of them are dedicated to scientific areas. Each council encompasses a wide array of scientific disciplines and represents a macroscience. For example, the Engineering and Physical Sciences Research Council involves the fields of mathematics, chemistry, physics, engineering, computer science, and more (Research Councils UK, 2014). According to Evans and Marvin (2006), the differences between these fields are minor and simply variations of the same ideas or principles. They also imply that collaborations between these fields are not, in fact, interdisciplinary because these fields share the same paradigms and frameworks.

This false assumption is prevalent in fields outside the sciences, but is also present, to a certain degree, within the sciences. Collaboration between different scientific fields is interdisciplinary and the differences between these fields can be significant. Philip Lowe and Jeremy Phillipson (2009) criticized the work of Evans and Marvin (2006) as follows:

The implication would be that interdisciplinarity is relatively unproblematic within the macrosciences. However, each of these embraces multiple competing paradigms. If anything, the tensions and rivalry between paradigms within the same macroscience community, say, between institutional and neoclassical economics, or between holistic and genomic ecology, may be more intense, as they are much more directly competitive in presenting mutually exclusive conceptualisations of the same phenomena. (pg. 1173)

Regardless of the reason, most scholars make sweeping generalizations about the detrimental impact that disciplinary differences have on collaborative success without actually identifying any tangible differences or describing their specific impact. The challenge of overcoming differences between collaborators can be exacerbated by a lack of awareness or identification of these differences. Therefore, additional research is necessary to identify the specific differences that exist between scientific disciplines. We need to understand how these differences impact the collaboration and are successfully negotiated to meet a cohesive resolution. The following study addresses this research need with respect to the development of a research proposal and offers insight useful to interdisciplinary collaborations and funding agencies.

2.3 CONCEPT OF BOUNDARY OBJECTS

The application of the concept of boundary objects to my analysis of interdisciplinary and collaborative proposal development is an effective and structured way to gain insight into this process. This concept was first defined by Star and Griesemer (1989) who realized that scientific inquiry involved and often required the cooperation of multiple and differing groups. To gain insight into the tension created by the differences between these groups, these scholars developed the concept of boundary objects.

Star and Griesemer (1989) observed a limitation in actor network theory and the idea of *interessement*. These scholars describe *interessement* as the process by which actors create scientific authority by enlisting a variety of participants and then molding their concerns to those of the position of authority. These actors then become established spokesmen or gatekeepers for the network. Star and Griesemer (1989) suggest that scientific work becomes complicated when multiple actors from different networks, or disciplines, are attempting this process at the same

time. Each person is trying to maintain their own identity and those of their collaborators, but still work together on a central problem to produce reliable and valid knowledge that functions across social worlds. Therefore, the molding of concerns towards a single authoritative position is resisted. Due to this complication, Star and Griesemer (1989) suggest a more ecological approach that does not assume the superiority of one viewpoint over another. This approach also enables one to view collaborative work as a balance between the level of coherence and maintaining the collaboration. Star and Griesemer (1989) developed an analytical tool to observe this collaborative situation and defined the concept of boundary objects as follows:

This is an analytic concept of those scientific objects which both inhabit several intersecting social worlds and satisfy the informational requirements of each of them. Boundary objects are objects which are both plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. These objects may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable. (Star & Griesemer, 1989, p. 393)

The term “social world” does not refer to a group of individuals, but instead to a source of common features, attitudes, ideas, and practices. Social worlds can include scientific disciplines, professional positions, and institutions. A single individual can embody multiple social worlds.

Boundary objects, either abstract or concrete, are recognized and intersected by two or more social worlds. Therefore, these objects have a rigid and universally understood form and function, as well as plastic elements that allow the object to adapt to the specific needs of individual social worlds. These characteristics also enable the objects to exist in the boundaries between social worlds, allowing multiple worlds to connect and interact (Schryer, 2011; Schryer et al., 2009; Star & Griesemer, 1989). Boundary objects, either solitary or as a system, become the sites for the negotiation of these different identities and viewpoints (Schryer, 2011).

Examples of boundary objects that occur between and are used in different scientific disciplines include genres, computer software, statistical methods, and machines.

The analysis of boundary objects used by an interdisciplinary team can provide insight into the associated collaborative process. For example, Schryer, Afros, Mian, Spafford and Lingard (2009) used the concept of boundary objects to understand the rhetorical strategies used by physicians, social workers, and lawyers with respect to child maltreatment forensic reports. Schryer et al. (2009) determined that the reports acted as a boundary object because they enabled each community to cooperate and negotiate social differences in an effort to protect child safety. Specifically, Schryer et al. (2009) observed that each of the worlds interacted with these reports differently. Physicians, within their medical practices, tend to make conclusions and diagnoses based on information gathered through observations and tests. There is some degree of judgment in this process. In contrast, the court system relies on facts, objectivity, and the consideration of alternative explanations. In order to work together to report and prevent further child maltreatment, the physicians and court system needed to reconcile these differences. Analysis of the boundary object enabled Schryer et al. (2009) to identify and confirm this tension between the social worlds that were intersected by the boundary object, and how these tensions were resolved. For example, physicians were able to alter the language they used in the reports to demonstrate a more objective diagnosis that was both accepted by and more functional within the legal system (Schryer et al., 2009).

With respect to this study, the concept of boundary objects can support numerous inquiries. First, identification of boundary objects used by a proposal team offers insight into the sites where team members interact and how this interaction might be framed. Second, analysis of the social worlds that are intersected by the object can reveal specific differences between

collaborators that potentially cause conflict and require negotiation. Finally, examination of the object throughout the collaborative process can reveal how these differences are successfully negotiated and resolved to produce a cohesive proposal, and potentially win funding.

Collaborations involving members from different scientific disciplines are complex and contextual. Additional research is necessary to further understand this complexity and how interdisciplinary collaborations successfully function to produce new knowledge in the face of a diverse membership and varying degrees of consensus. The concept of boundary objects can offer an effective framework to structure further inquiry into this process as it relates to proposal development.

2.4 RESEARCH PROPOSAL GENRE AND SUBGENRE

The concept of boundary objects can be expanded to genres and further inform this study. In general, genres are considered disciplinary constructs. However, some genres are not isolated to specific disciplines and instead, span numerous fields or occur between these fields. Since the focus of this research is on the interdisciplinary and collaborative development of a research proposal, an understanding of genre and its relation to disciplines is essential.

Scientific disciplines have a complex relationship with genres, developing and depending on them to accomplish repeated tasks. Genres can be understood as texts that share features such as structure, style, and content, as well as forms of repeated social action or rhetorical situations (Bawarshi & Reiff, 2010; Miller, 1984; Russell, 1997). When communities are faced with a situation, rhetorical discourse is a common tool used to invoke action to address the situation. When these problems recur, the community repeats the specific discourse and thus creates a genre (Bazerman, 1988; Miller, 1984). Bazerman (1988) states that

a genre is a socially recognized, repeated strategy for achieving similar goals in situations socially perceived as being similar. A genre provides a writer with a way of formulating responses in certain circumstances and a reader a way of recognizing the kind of message being transmitted.... Thus the formal features that are shared by the corpus of texts in a genre and by which we usually recognize a text's inclusion in a genre, are the linguistic/symbolic solution to a problem in social interaction. (p. 62)

The research proposal is one example of a genre readily used to persuade a funder to monetarily back a research endeavor. This genre is interesting because it is manipulated and used by almost all scientific disciplines. The research proposal genre is characterized by a common structure and function. In general, proposals, synonymously referred to as grants, are solicited by federal agencies, industry, and non-profit organizations. Once they are solicited, interested researchers develop and present a research design in text form that addresses the funder's needs and will, hopefully, win funding (Connor, 2000; Connor & Mauranen, 1999; Myers, 1985, 1990). The common structure of a proposal, however, is not sufficient to induce action because it lacks discipline specific information that is necessary for effective persuasion. Therefore, in order to be effective, the research proposal genre is broken down into functional subgenres per discipline. These subgenres occur simultaneously across disciplines and demonstrate a degree of variability in structure (Holmes, 1997).

For genres to effectively prompt a community into action, they need to embody the norms, values, and goals of that community in order to be persuasive (O'Neill, 2001). To do this, disciplines take advantage of the fact that genres are "stabilized-for-now" in that they can be maintained or altered to adapt to the changing needs of a community and the situation (Schryer, Lingard, Spafford, & Garwood, 2003). Scientific disciplines therefore develop their own, highly specific proposal subgenres by maintaining the common form and structure of the genre and by manipulating the plastic elements to address their own disciplinary needs.

Ulla Connor, an English professor specializing in English as a Second Language (ESL), and Anna Mauranen, an expert in discourse analysis, have studied the research proposal genre. These scholars suggest that persuasion for funding is accomplished by carefully appealing to the requesting agency. This is accomplished, in part, by demonstrating the ability to carry out the proposed work through sufficient background knowledge; by demonstrating the feasibility of the research through chosen methods, paradigms, and access to resources; and by showing the significance of research findings through proposed advances in knowledge creation (Connor and Mauranen, 1999). Each of these rhetorical strategies used in the proposal reflects the situated disciplinary knowledge of the author and in turn, specifically appeals to the disciplinary knowledge of the reviewers who represent the agency (Hyland, 2007). This disciplinary knowledge is absolutely necessary to develop an effective proposal that achieves the desired action of funding.

The disciplinary knowledge described above is a component of genre knowledge. Christine Tardy (2003), an expert in genre and discourse studies, defines genre knowledge as follows:

Genre knowledge... consists of both formal generic conventions as well as generic content, which may include complex understandings of epistemology, background knowledge, surprise value, and kairos (rhetorical timing) as they relate to the disciplinary community in which the genre is situated. (p. 28)

With respect to the proposal subgenres, Tardy (2003) determined that genre knowledge was dictated by the disciplines and their specific contexts. In addition, this knowledge was not limited to the proposal form and content, but also encompassed a level of understanding of the entire funding system, related genres, and interested parties relevant to a specific context (Tardy, 2003). Tardy (2003) observed that much of this knowledge was gained through formal mentor / apprentice relationships and from community participation.

As Tardy (2003) alludes to, genre knowledge also encompasses a detailed understanding of a discourse's genre ecology. Clay Spinuzzi, a prominent scholar in genre theory, activity theory, and rhetoric, developed the concept of genre ecology to describe how multiple genres and people interact in order to accomplish activities (Spinuzzi, 2002, 2003, 2004). With origins in genre theory and activity theory, Spinuzzi (2003) states that a genre ecology framework is "an analytical framework for studying how people use multiple artifacts – such as documentation, interfaces, and annotations – to mediate their work activities... the genre ecology framework is centrally concerned with how people interpret genres, how they contingently intermediate genres, and these contingencies become relatively stable over time" (p. 200). Adding an understanding of the genre ecology of a research proposal to one's genre knowledge is valuable. Knowing the types and ways different factors mediate proposal development can improve an individual's ability to navigate the funding process and write a relevant proposal.

A researcher who possesses genre knowledge of proposals has an intricate and thorough understanding of his or her discipline (O'Neill, 2001) and the associated genre ecology. When embodied by a proposal, this knowledge can make the document highly persuasive and relevant to a specific discipline. However, as mentioned previously, the proposal genre can occur between disciplines. Looking at the research proposal genre as a boundary object complicates our understanding of genre, taking it out of a disciplinary realm and placing it into an interdisciplinary context. Interdisciplinary and collaborative research proposals force the integration and negotiation of multiple proposal subgenres and therefore, differing sets of genre knowledge to create a cohesive research proposal. Further analysis of genres as boundary objects can offer insight into interdisciplinary collaborations and how genre knowledge, as a representation of disciplinary character, is negotiated and integrated.

CHAPTER 3

METHODOLOGY

In this chapter, I offer a detailed explanation of the multiple methodologies used to examine the interdisciplinary and collaborative development of a research proposal. Findings produced by these methods offer insight into the complexities of this process. Using the concept of boundary objects as a foundation, I addressed the aims previously detailed in Chapter 1:

- Aim 1: Identify the essential boundary objects used by a scientific interdisciplinary collaborative team in the development of a research proposal.
- Aim 2: Identify and describe the informational requirements of the primary essential boundary object and the social worlds that it intersects.
- Aim 3: Examine the primary essential boundary object to determine what and how factors are negotiated between the members of the scientific interdisciplinary collaborative team in order to develop the research proposal.
- Aim 4: a) Determine if the negotiations conducted through the primary essential boundary object were successful in producing a rhetorical document; b) Determine if the negotiations conducted through the primary essential boundary object were successful in persuading an award of funding.

I addressed these aims by observing an interdisciplinary and collaborative team of scientists as they developed a federal research proposal. I collected data through a variety of qualitative methods including:

- Interview protocol
- Demographic analysis

- Meeting observations
- Email and track-changes protocol
- Textual analyses

The use of multiple qualitative approaches enabled me to observe as many interactions between collaborators as possible during the development of the Ecology and Evolution of Infectious Disease (EEID) proposal. Therefore, I was able to observe and effectively describe the majority of the process of interdisciplinary collaboration. In addition, this approach afforded flexibility in my analyses over time. Through my data collection and initial analysis protocols, emerging findings and themes changed some of the later analytical requirements (Creswell, 2012). Specifically, the types of textual analyses that I conducted depended upon what boundary object was identified. Due to this research design, my general methods are described in this chapter. The data analysis protocols that were dependent upon emerging findings are described in following chapters.

My varied academic and professional background assisted in the development and execution of these methods, and offered a unique perspective during analysis. I have crossed disciplinary boundaries and have received academic training in both the sciences and English. I have an undergraduate degree in biology, a Master of Science degree in molecular, cellular, and systems physiology, and am working towards a doctorate in English. My professional experience is equally as varied. Over time, I gained experience designing and conducting empirical research in the fields of microbiology, molecular biology, physiology, ecology, and others. Due to an interest and ability in writing, I transitioned the focus of my work and education to proposal writing. Over the past 13 years, I have participated in the development and submission of well over 250 proposals. The level of my participation has ranged from the

contribution of small sections and basic editing, to the management, writing, and submission of the entire effort. The topics of these proposals have also been varied, from modeling and simulation of infectious disease, to the physiology of the neural system, to the test and evaluation of military aircraft. As an individual trained in both the sciences and English, and as a proposal manager, I have a unique ability to analyze and draw conclusions concerning the interdisciplinary and collaborative development of a research proposal.

My study was proposed to and approved by the Old Dominion University (ODU) Institutional Review Board (IRB) prior to study commencement on September 18, 2014. The IRB approval letter and a copy of the informed consent form can be viewed in Appendix A and Appendix B, respectively.

3.1 PARTICIPANT SELECTION

I identified and approached potential teams of proposal writers through my professional and academic connections. I needed the collaborative team to have a series of specific qualities in order to effectively inform the study. First, the team had to include two or more individuals from two or more academic disciplines. This enabled me to characterize the team itself as collaborative and interdisciplinary. The second criterion was that each member of the team needed to be actively involved in proposal development. Fulfilling this requirement ensured that the team's proposal development process was interdisciplinary as opposed to multi-disciplinary, and that different collaborators/disciplines would participate in negotiations.

My third criterion for participant selection was that the entire team had to agree to this study. This requirement improved the quality of my data because teasing out the contributions and impacts of a non-participating team member would have been impossible and led to skewed

or inaccurate findings. Finally, I had to identify a team that I had never worked with. This requirement allowed me to remain an outside observer and increased my ability to conduct objective analyses due to minimized interaction with the team and their research.

With the assistance of my committee members, we identified a team that fulfilled all of the requirements detailed above. We contacted each potential participant and provided a study description and consent form that were approved by the IRB. Informed consent was obtained from each participant and all protocols adhered to ODU IRB standards. Each individual agreed to participate in the study through the proposal development process. During a three-month period, the participants agreed to have me observe group e-mail correspondence, read written drafts of proposal documents and associated edits, and observe with note-taking, face-to-face, phone or Skype meetings. Team members also agreed to participate in a 45-minute voice recorded interview.

Throughout the data collection and analysis, I took measures to protect the anonymity of the participants and the confidentiality of their proposed research. Following data collection, I assigned a pseudonym to each participant and removed all references to their specific academic institutions. This process protected the identity of the participants. In addition, the proposal content was proprietary. In order to protect the confidentiality of this information, I minimized the use of direct quotes from the proposal text. If quotes were necessary, I removed specific terminology or names and replaced the text with “XXX.” To reduce my dependence on the specific language of the proposal to support my findings, I primarily relied on interview data, emails, meeting observations, reviewer comments, and paraphrasing. Finally, I had the Principal Investigator (PI) of the proposal effort review and confirm that my final reporting revealed no personally identifiable information (PII) or proprietary data.

3.2 DERIVATION OF THE ANALYTICAL FOUNDATION

I used the definitions of a boundary object provided by Star and Griesemer (1989) and Schryer et al. (2009) to develop the analytical foundation for my study. As discussed in Chapter 2, Star and Griesemer (1989) described the three primary qualities of a boundary object, which included having a status, intersecting two or more social worlds, and satisfying the informational requirements of each world. In addition, Schryer et al. (2009) defined a boundary object as something that enabled each community to cooperate and negotiate social differences to create action. By combining these descriptions of a boundary object, I determined the four criteria used to frame the identification and examination protocols of my study:

- Status: Having an abstract or concrete state of being;
- Intersecting social worlds: Inhabiting two or more intersecting social worlds;
- Informational requirements: Satisfying the informational requirements of two or more social worlds, having both a common identity and plasticity in meaning and structure across these worlds;
- Negotiation: Enabling negotiation of social differences to produce action.

First, I used these defining criteria to identify potential boundary objects. Following an initial screen, objects of interest were compared to the definition in detail. If they fulfilled all of the criteria listed above, they qualified as a boundary object. I also used these criteria to focus an in-depth analysis on one boundary object. Specifically, I used a combination of data obtained from my multiple methods to examine the intersecting social worlds, informational requirements, and negotiations that occurred through the object. Table 1 demonstrates the methods used to inform the analysis of the boundary object.

Table 1. *Methods used to inform the description of the boundary object per defined criteria*

	Boundary Object Identification (Aim 1)	Intersecting Social Worlds (Aim 2)	Informational Requirements (Aim 2)	Boundary Object Negotiations (Aims 3 & 4)
Supporting Methods	Interview protocol Meeting observation Email protocol	Interview protocol Demographic analysis	Interview protocol Textual analyses	Interview protocol Demographic analysis Meeting observation Email and track-changes protocol Textual analyses

The combinations of methods and resulting data depicted in Table 1 supported the description and further analysis of the chosen boundary object. Subsequently, these analyses provided valuable insight into the entire collaborative process. I discuss each of these supporting methods in detail in the following sections.

3.3 INTERVIEW PROTOCOL

The interview protocol was integral to the study and informed each component of the boundary object analysis. I chose the format of a semi-structured interview to focus the topic of conversation, but to also allow participants to elaborate on each topic. The resulting data from the interviews demonstrated participant perceptions of disciplinary identity and their

understanding of the proposal development process. The data also supported the identification of potential boundary objects used during the collaboration.

3.3.1 Data collection. Following the acquisition of informed consent, I scheduled semi-structured interviews with willing participants. Interviews were scheduled within the first half of the EEID proposal development process. I conducted the interviews via phone or Skype and they ranged between 40 - 45 minutes in duration. I recorded each interview with a voice recorder for future transcription. Each interview followed a set script (Appendix C) that was structured into three sections. The first section focused on disciplinary identity and was designed to address Aim 2. I asked questions pertaining to professional position, stage in career, associated disciplines, and professional goals. I then asked the interviewees to elaborate upon perceived differences between their associated disciplines and those of their teammates', particularly with respect to disciplinary values, writing style, and the meaning of success.

The second section of the interview addressed the participant perceptions of the EEID proposal and its development (Aim 2). I asked each interviewee to identify and reflect on his or her contributions to the EEID proposal, goals for this proposal, processes for methods and proposal development, and experiences and biases towards collaboration. The third section of the interview was focused on describing the objects and tools each participant used to develop a proposal, design methods, and communicate with collaborators. I introduced the concept of boundary objects at this point and the interviewees were asked to identify potential boundary objects that they use in the proposal process. I designed this series of questions to assist in identifying potential boundary objects (Aim 1). The responses to the interview questions across

all sections were also applicable to and further supported Aims 3 and 4 by providing insight into the disciplinary factors that were negotiated through specific sites in the EEID proposal.

3.3.2 Data analysis. Following each interview, I uploaded the full voice recordings to a web-based application called *Transcribe* (<http://transcribe.wreally.com>). Within this application, I manually transcribed the recordings to text and saved the files as Word documents. The interview text was then coded to identify broad and recurring themes. I started the coding analysis of the interviews by first examining each question separately. Within each question, I identified and labeled significant or recurring text segments and concepts with a code word or phrase. Following this process, I compiled the codes, grouped similar codes, and identified themes by question (Creswell, 2012). I also recorded the number of participants who addressed each code instead of recording the number of instances each code occurred per question. I did this to reduce bias in a code's significance caused by the participants' tendency to repeat terms and sentences in speech. Recording instance at the participant level provided a better representation of the importance of each code.

Following collection by question, I examined and organized the codes across the interview segments including disciplinary identity, proposal development, and boundary object identification (Creswell, 2012). This process was repeated for each interview. In order to validate my coding analysis, a collaborator reviewed my codes and de-identified interview text. She confirmed that all codes were present and appropriate.

The compilation of final codes enabled me to conduct additional analyses to determine overarching themes, identify specific boundary objects, characterize social worlds, understand

informational requirements and examine topics of negotiation. Detailed descriptions of how this data was used to support additional analyses and each aim are located in the following chapters.

3.4 DEMOGRAPHIC ANALYSIS

The demographic analysis was designed to gain additional insight into each participant and the characteristics of their associated social worlds. I used this data, in combination with other protocol outcomes, to demonstrate the variability in participant demographics, describe social worlds, and to analyze the negotiation of social differences between collaborators (Aims 2 & 4).

3.4.1 Data collection. I created participant profiles for each individual involved in the study. I obtained demographic data through the observation of university webpages, biographical webpages, direct inquiry, and via interview questioning. I recorded general demographic information on each participant including gender, nationality, and current geographical location. I also collected professional demographic information on each participant including his or her current employing institution, the type of institution (academic, government, or industry), and its geographic location. I also collected the participant's current professional position, the next professional position to attain, tenure status, and if applicable, his or her associated department and college. Finally, I collected disciplinary demographic information including each participant's primary discipline(s), sub- discipline(s), and the degrees obtained in these fields. All of the data were collected in a master excel spreadsheet for analysis.

3.4.2 Data analysis. Following data collection, I tallied the data per specific demographic categories including gender, nationality, current geographic location by state, the type and location of each participant's institution, and their professional positions. The number of participants per primary and sub-discipline were also tallied. This data were de-identified and further analyses are discussed in detail in Chapter 4.

3.5 MEETING OBSERVATIONS

The observation of meetings gave me an opportunity to witness boundary objects in use and the real-time negotiations that occurred through these objects. I observed three meetings through the course of proposal development. These meetings involved between two to four team members and were conducted via Skype. Each time, I participated as a silent and invisible observer. This strategy minimized my presence in and impact on the meeting. During each meeting, I took detailed notes with respect to participant and scene descriptions, tools used for collaboration, topics of conversation, contributions to proposal development, points of conflict or debate, and reactions to the National Science Foundation (NSF) guidelines and reviewer comments. These observations were used to identify potential boundary objects (Aim 1) and acted as examples to support my analyses of negotiations (Aims 3 & 4).

3.6 EMAIL AND TRACK-CHANGES PROTOCOL

In order to observe additional interactions and gain a better understanding of the collaborative process in its entirety, I collected email correspondence through the duration of proposal development. In addition, I gathered the track-changes comments written across all drafts of the project description in the EEID proposal. I chose to analyze the project description

because this section covers the entire research plan, from stating research goals and aims to describing the methods and potential contributions in detail. This material therefore demonstrated negotiations across the breadth of the proposal elements. The email and track-changes exchanges between collaborators assisted in the identification of boundary objects and offered insight into the negotiation of social differences (Aims 1, 3 & 4).

3.6.1 Data collection. The PI for the effort was integral in making sure that I received the email correspondence. She carbon copied (cc) me on all email conversations that she initiated or responded to. In addition, the PI forwarded any remaining email chains that she was aware of. Finally, all of the other participants were aware of my involvement and also cc'd me on their correspondence if it did not involve the PI.

In addition to emails, I collected all of the edits and comments that were made in the sequential drafts of the project description in the EEID proposal. The team used Dropbox, a cloud-based service for file hosting, to store all documents pertaining to the proposal. These documents included all drafts of the project description. Through proposal development, each collaborator edited sequential drafts of this section by downloading the latest version and using the track-changes feature in Microsoft Word to make suggested edits and comments. This feature also recorded the time and author of each edit and comment. Once complete, the collaborator uploaded a new version with the current date and their initials in the file name. Additionally, Dropbox time-stamped the upload and identified the individual responsible. This process resulted in a collection of project description drafts within Dropbox.

I downloaded all of these drafts and used the information recorded in the file names, by Dropbox, and through the track-changes feature to place the documents, edits, and comments in

sequential order and identify responsible authors. This allowed me to organize and analyze the editing and comment contributions made by individual participants through time.

3.6.2 Data analysis. I coded the text of all collected emails and track-changes comments by the same method described under the interview protocol. I analyzed the text for recurring or significant terms and concepts and assigned a code to each. I then grouped similar codes and compiled the codes across all emails. In addition, I recorded the number of times each code occurred in the email text. I independently repeated this process for the comments text. All of my codes were confirmed and approved by a collaborator in the same manner as described in the interview protocol. Further analysis and application of this data is described in detail in Chapter 6.

3.7 ANALYSES OF TEXTS

The analyses of numerous texts were necessary to address Aims 2, 3 and 4. The need for and design of these analyses were shaped by findings from the interview, meeting observation, and email and track-changes protocols. Therefore, the analyses of texts are not detailed here, but are described in the relevant sections of Chapters 4, 5 and 6.

The methods discussed above were designed to maximize the amount of information that I could collect on the interdisciplinary and collaborative process during proposal development. In addition, these methods allowed for change and adaptation as new findings emerged, which are discussed in subsequent chapters. The flexibility of my design and ability to combine different data and findings to address each aim enabled me to gain greater insight into the

boundary object of interest, the negotiation of social differences, and the impact of multiple external factors.

CHAPTER 4

IDENTIFICATION AND DESCRIPTION OF THE PROPOSAL

BOUNDARY OBJECT

This chapter discusses the initial analyses that I performed in my study of the boundary objects used by an interdisciplinary and collaborative proposal team. Specifically, I focused on identifying the primary and essential boundary object used by the scientific research team to develop a funding proposal. Through the identification and initial description of this object, I was able to gain insight into the disciplines that were involved and their unique characteristics.

4.1 STUDY QUALIFICATIONS

The protocols for data collection discussed in Chapter 3 began on October 1, 2014 and continued through the receipt of the funding notice and reviewer comments on March 18, 2015. These protocols produced a significant amount of data that offered numerous avenues for inquiry. I developed a set of parameters to focus my analysis and maintain a manageable and productive scope for the project. Application of these parameters enabled me to conduct a more detailed and in-depth examination of the data, which resulted in more concise conclusions.

The first parameter that I used was to focus my analysis on a single essential boundary object as opposed to a system. The identification of the object, the Ecology and Evolution of Infectious Disease (EEID) proposal, and the social worlds it intersects are discussed in this chapter. Numerous social worlds were connected to the proposal, including multiple institutions, disciplines, gender, nationality, the funding agency, and others. Analysis of all of these worlds was not reasonable given the scope of the project. Therefore, the second parameter that I used

for the study focused my analysis on a set of social worlds which was comprised of the five disciplines that contributed the most to proposal production. The final parameter focused my analysis of the negotiation factors that I identified. I chose to limit my analysis to three negotiation factors that were most prominent in the data and interestingly, highly relevant to disciplinary identity and informational plasticity.

The data that fell outside of my established analytical parameters remains useful and potentially informative. Therefore, this data can serve as excellent points for future research endeavors.

4.2 BOUNDARY OBJECT IDENTIFICATION

4.2.1 Participant selection. As described in the methods chapter, I successfully identified and recruited an interdisciplinary and collaborative team of scientists who were in the process of developing a research proposal. Specifically, this team collaborated to revise and resubmit a research proposal in response to a program solicitation, number NSF 14-592, from the National Science Foundation's (NSF) EEID Program (Scheiner et al., 2014). Within this study, both the program solicitation and request for proposals (RFP) refer to the same document, making the names interchangeable. The team successfully developed and submitted the proposal to the NSF on November 19, 2014. However, the NSF did not award funding. I discuss this outcome in detail in Chapter 6.

The recruited proposal team fulfilled the collaborative and interdisciplinary criteria that were detailed in the methods chapter. The 13 members of the team represented 10 different primary scientific disciplines. All of these participants were actively involved in proposal

development. In addition, the demographics of the team were varied, including both male and female participants who were at different stages in their professional careers and were associated with different academic institutions. Brief descriptions of these participants are provided below. I assigned a pseudonym to each individual in order to protect their identity during data analysis and reporting.

Anne. The most prominent participant, Anne, was responsible for initiating and managing the entire proposal effort. Her background was in mathematics and biology, and she was a recently tenured Associate Professor. Anne's research focus aligned directly with the EEID proposal, making her a prime candidate for running the effort. As a result, Anne took on the roles of coordinating the team, delegating tasks, managing the writing process, finalizing the proposal, and interfacing with the government agency.

Jim. Jim was actively involved in proposal production. His background was focused in general and behavioral ecology. In addition, he served as an Assistant Professor at the same university as Anne. Jim had extensive experience with proposal development and contributed to the writing and editing of specific sections of the EEID proposal.

Mike. Mike was a tenured Full Professor whose field of expertise was molecular biology. His disciplinary background and proposal writing experience made him a significant contributor to the molecular biology components of the EEID proposal. He also offered focused editing suggestions throughout the drafting process.

Amir. Similar to Mike, Amir was a molecular biologist and a Full Professor. However, Amir's participation in the proposal production was limited to minor conceptual contributions. He did not participate in the writing or editing activities for this EEID proposal submission.

Craig. Craig was a Full Professor and a Department Chair at his university. His background was focused in microbiology and he offered significant expertise from his field. Craig actively participated in developing the microbiology and molecular biology protocols for the proposal. He also participated in writing and editing these sections.

Jen. Jen was a prominent member of the EEID team. She participated readily in content discussions and frequently offered editing suggestions pertaining to all sections of the EEID proposal. Jen's background was in general and disease ecology as well as geography. She was not yet tenured and held the position of Assistant Professor at her university.

Matt. Matt was an Assistant Professor with a background in disease ecology and epidemiology. He was the second most active participant in proposal development next to Anne. Matt was responsible for revising and writing a significant portion of the research methods that had to do with the field studies. He coordinated other participants, offered many content suggestions, initiated numerous discussions, and was heavily involved with the overall editing of the proposal.

Simon. Simon was one of the mathematicians on the team with an expertise in modeling infectious disease. He was an Associate Professor at his university in Africa. Simon offered insight into the modeling protocol, but had little involvement in writing and editing.

Adashe. Adashe was one of the youngest members of the team and filled the position of a Lecturer and Post-Doctoral Fellow at his university in Africa. His area of focus was Pathology and he made content contributions to the microbiology and field protocols discussed in the EEID proposal. Adashe also provided many editing suggestions throughout the proposal drafts.

Mark. Mark, a Full Professor, offered expertise from his field of microbiology. In addition, he was highly concerned with the finer points of proposal development due to his

experience as a reviewer for federal proposals. Mark frequently offered methods suggestions to tailor the research plan to agency priorities.

Maguri, Shandu, and Tsebo. The remaining participants, Maguri, Shandu, and Tsebo, all played a minor role in the development of this proposal. Maguri, a parasitologist, and Shandu, a mathematician, were both Deans and Full Professors at the same university in Africa. Tsebo was the only participant who had expertise in veterinary science and worked for a government agency in Africa.

All the participants involved in the EEID team agreed to participate in the study and signed a letter of consent in accordance with the Old Dominion University (ODU) Institutional Review Board (IRB) (Appendix B).

4.2.2 Boundary object identification. Following participant recruitment, the first phase of the study involved the identification of boundary objects. I accomplished this goal by using the analytical foundation described in the methods chapter. The specific characteristics of a boundary object, including the intersection of multiple social worlds, satisfying the informational requirements of those worlds, and enabling negotiation to produce action, provided the initial criteria for identifying potential boundary objects in interview coding data as well as through direct observation.

The interview data was particularly useful in this identification process. I conducted a total of five 45-minute interviews between October 9, 2014 and October 28, 2014. Anne, Jim, Mike, Amir and Craig participated in these interviews and responded to a variety of questions, a selection of which were focused on boundary object identification. I then coded these responses and subsequently identified multiple objects that appeared to meet the boundary object criteria.

In accordance with the previously discussed parameters set for this study, I limited further examination of the objects to those that demonstrated the greatest potential to meet all boundary object criteria. I also selected objects that appeared essential to proposal development. The classification of ‘essential’ referred to those objects that were integral in informing and shaping proposal development, facilitated negotiations between disciplines, and had clear connections to other boundary objects. The essential boundary objects are listed in Table 2. The number of participants who referred to a specific object is represented by “n.”

Table 2. *Identified essential boundary objects from the interview coding data*

Essential Boundary Objects
EEID Proposal (primary) <i>n=5</i>
Mathematical Model <i>n=5</i>
Program solicitation / RFP <i>n=1</i>
Reviewer Comments (email and meeting observations)

I identified four essential boundary objects that fulfilled the established defining criteria. Specifically, all five participants confirmed that the EEID proposal qualified as a boundary object during the interview protocol. The proposal acted as the main nexus and stimulus for negotiations between each collaborator. The mathematical model was also identified as a boundary object by all five interviewees due to its position as a nexus for methodological negotiations between collaborators. Although only mentioned by one individual, the RFP played a critical role in proposal development. I therefore categorized the RFP as an essential boundary object. In addition, observation of emails and meetings revealed that the reviewer comments

qualified as boundary objects and significantly framed proposal development. Both the RFP and reviewer comments were significant in that they facilitated negotiations between each team member as well as between the team and the funding agency. All of these objects and their interrelations will be discussed further in subsequent chapters.

Following the identification of the essential boundary objects, I proceeded to narrow the focus of the study yet again. I selected the EEID proposal for in-depth analysis as the primary essential boundary object. This was done because data from the interview protocol and initial observations clearly demonstrated that the EEID proposal itself was the most prominent object of interest. Without this object, the team would not have initiated the collaboration or had reason to negotiate. In addition, this single document was understood by each discipline individually, and acted as the tangible nexus for the collaborative negotiations of knowledge, methods, and purposes. Finally, the proposal was an accessible object for analysis that could provide insight into the collaborative process. Therefore, I focused the remaining analyses on the EEID proposal.

4.3 EEID PROPOSAL BOUNDARY OBJECT DESCRIPTION: STATUS

4.3.1 Status. The first criterion that a potential boundary object had to meet was that of status, in either a concrete or abstract form. In the case of the EEID proposal, the document had a mixed status. The proposal had a physical manifestation of text on paper or screen and was therefore concrete. The proposal text also took an abstract form as it was read and mentally processed by the collaborators and reviewers.

4.4 EEID PROPOSAL BOUNDARY OBJECT DESCRIPTION: SOCIAL WORLDS

4.4.1 Intersecting social worlds. The second criterion for boundary object designation was the necessity for the object to intersect two or more social worlds. The EEID proposal fulfilled this criterion on multiple levels by crossing through varied academic institutions, the multiple disciplines represented on the team, and the involvement of the funding agency and reviewers. I chose to focus my analysis on the social worlds of the research collaborators as opposed to the agency and reviewers due to the accessibility of team member data.

Each collaborator represented a unique combination of social worlds. The two most prominent worlds were their affiliated institutions and associated scientific disciplines. These social worlds intersected, overlapped, or differed between collaborators, resulting in an intricate web of commonalities and differences that required negotiation to create one cohesive proposal. To gain insight into this situation and to define the characteristics of the prominent social worlds involved in the proposal, I examined interview coding data, used direct participant inquiry, and performed internet and literature searches.

The individual collaborator. My analysis revealed that each collaborator embodied multiple social worlds. Each individual had a specific combination of disciplinary training, research endeavors, jobs and requirements, collaborative work, life experiences and more. These varied experiences stemmed from multiple social worlds and produced a complex and unique identity. In turn, these identities influenced each person's understanding of his or her role in the development of the EEID proposal. In addition, variability in these characteristics led to the formation of unique motivations, priorities, goals, collaborative methods, and disciplinary

identities. Therefore, each collaborator embodied a unique set of social worlds and therefore had an individualized set of factors to negotiate through the EEID proposal boundary object.

To illustrate this variability, the general demographic characteristics of the collaborators are summarized in Table 3.

Table 3. *Summary of general demographics of participants (de-identified data)*

Demographic	Detail	# EEID Participants
Gender	Male	11
	Female	2
Nationality	North American	5
	New Zealander	1
	Pakistani	1
	Canadian	1
	South African	2
	Zimbabwean	2
	Kenyan	1
Current Geographic Location	United States: Virginia	5
	United States: Florida	2
	United States: Mississippi	1
	South Africa: Durban	4
	South Africa: Eastern Cape Province	1
Total # of Participants: 13		

The team of participants was predominantly comprised of males (11), with only two females. In addition, the group was culturally diverse and individuals represented seven nationalities including North American, New Zealander, Pakistani, Canadian, South African, Zimbabwean,

and Kenyan. However, the collaborators' nationalities did not necessarily reflect their current geographic location. The participants spanned two countries, the United States and South Africa. Within the United States, Virginia, Florida, and Mississippi were represented. Within South Africa, Durban and the Eastern Cape Province were represented.

The general demographics of the EEID collaborator group demonstrated considerable gender, cultural, and geographical diversity within this relatively small participant pool. The variability demonstrated by this data emphasized the individuality of each collaborator's context and unique combination of social worlds. In addition to institutional, disciplinary, and other components of identity, these demographic characteristics translated into a unique set of factors that each collaborator negotiated in the development of the EEID proposal. Gender, cultural, and geographic differences between collaborators are increasingly common in the sciences. Women continue to enter the once male dominated fields of science and advances in communication tools, among other factors, enable increased collaboration across nations (Committee on Women in Science & Engineering & Medicine, 2015; Wagner & Leydesdorff, 2005). The social worlds of gender, nationality, and location likely impacted the types of negotiations that occurred through the EEID proposal. However, these factors were not within the defined scope of this study. Therefore, this data may be used at a later date for future investigations.

Institutions. As mentioned earlier, one of the prominent social worlds that impacted each collaborator was their employing institution. Professional institutions, whether in industry or academia, establish processes, expectations, and regulations for employees to adhere to. Specifically, every institution mandates or infers specific milestones that must be achieved in order to advance to the next pay grade or level of responsibility, or to maintain employment in a senior position. Since career advancement and preservation is a common goal, most employees

strive to achieve these institutionally set milestones. One prominent milestone involves the acquisition of external research funding. This requirement prompts employees to actively seek funding opportunities, write proposals, and collaborate on research endeavors. This example demonstrates how institutional advancement and employment criteria can influence each individual's choices, motivations, and priorities. Therefore, professional institutions are social worlds that instill specific goals in their employees. This determines specific factors that each person must negotiate through the EEID proposal in order to meet their professional needs. In addition, the perceived importance of institutional milestones can shape how forcefully a person negotiates.

The professional demographics of the EEID team illustrate the number of different institutional social worlds that were involved and potentially impacted negotiations through the proposal. This data is summarized in Table 4.

Table 4. *Summary of the professional demographics of participants (de-identified data)*

Demographic	Detail	# EEID Participants
Institution Type	Academic University	12
	Government Agency	1
Institution Location	United States: Virginia (Norfolk)	4
	United States: Virginia (Richmond)	1
	United States: Florida	2
	United States: Mississippi	1
	South Africa: Durban	4
	South Africa: Eastern Cape Province	1
Professional Position	Post-Doctoral Fellow	1
	Assistant Professor	3
	Associate Professor	4
	Full Professor	4
	Research Scientist	1
Total # of Participants: 13		

Each participant was affiliated with one of six different institutions, five of which were academic and one a government agency. In addition to institutional variability, this group of collaborators represented the entire span of academic professional positions from a Post-Doctoral Fellow starting in his profession to Full Professors at the pinnacle of their careers. Specifically, the academics included one Post-Doctoral Fellow, three Assistant Professors, four Associate Professors, and four Full Professors. A single participant was associated with a government institution and was a Mid-Level Research Scientist. This participant pool adequately represented multiple institutional social worlds. As a result, members within this group likely negotiated a

variety of professional goals through the EEID proposal. Similar to the gender and cultural factors discussed above, institutional social worlds are significant and deserve mention; however, they were not within the scope of this study and will be addressed at a later date.

Disciplines. As demonstrated, each EEID participant's identity was a conglomeration of numerous and varied characteristics, developed through a lifetime of unique experiences and professional goals. However, one of the most influential factors that shaped the participant's identities was their associated scientific disciplines. Through training, practices, knowledge production, and unique worldviews, these communities of practice molded their members to think and act in specific ways, thus creating distinct social worlds (Klein, 2006; Krishnan, 2009; Wenger, 2006). More importantly however, these norms of thought, behavior, and knowledge differed between each scientific discipline. Therefore, reconciling differences between disciplinary social worlds to create a cohesive proposal required frequent negotiation.

My intent for this analysis was to demonstrate that each scientific discipline had a unique character, therefore qualifying each one as separate social world. In turn, this qualification would partially validate the EEID proposal as a boundary object. In addition, I hypothesized that this analysis would reveal disciplinary differences that existed between my participants and therefore suggest potential negotiation factors. This premise was based on the fact that multiple scholars have examined multi- or interdisciplinary collaborations and have suggested disciplinary differences as a potential barrier to successful productivity (Becher & Trowler, 2001; Evans & Marvin, 2006; Lele & Norgaard, 2005; Morse et al., 2007). However, a limited amount of research has taken the next step in outwardly defining scientific disciplines and identifying the specific differences that exist between them (Lele & Norgaard, 2005; Morse et al., 2007; Petts, Owens, & Bulkeley, 2008). Examination of the disciplinary social worlds

intersected by the EEID boundary object was an effective way to address this gap in knowledge and achieve my aims.

The first step in characterizing the involved scientific disciplines was through the identification of each collaborator's associated discipline(s). I determined the disciplinary identity of each participant through a combination of direct inquiry during the interview and their academic webpages. The five participants that were interviewed provided concise responses when I asked them to identify their disciplines. The remaining eight participants all had academic webpages that listed their associated disciplines. Eleven participants in the EEID proposal team identified with one primary discipline while the remaining participants identified with two. In addition, a total of eight participants identified with sub-disciplines, with one individual associating with a single sub-discipline and the remaining seven identifying with two. The academic disciplines of the EEID proposal team are summarized below in Table 5.

Table 5. *Summary of the disciplinary demographics of participants (de-identified data)*

Demographic	Detail	# EEID Participants
No. of Primary Disciplines	Single primary discipline	11
	Multiple primary disciplines	2
Primary Disciplines (*2 participants identified with 2 primary disciplines)	Mathematics	3
	Entomology	1
	Ecology	3
	Microbiology	1
	Molecular biology	2
	Parasitology	1
	Pathology	1
	Epidemiology	1
	Biology	1
	Immunology	1
Sub-disciplines (*8 participants identified with one or more sub-disciplines)	Education	1
	Ecology	1
	Epidemiology	1
	Pathology	1
	Bioinformatics	1
	Molecular biology	1
	Geography	2
	Entomology	1
Total # of Participants: 13		

Across all participants, 10 distinct primary scientific disciplines were represented and included mathematics, entomology, ecology, microbiology, molecular biology, parasitology, pathology, epidemiology, biology, and immunology. Within the discipline of ecology, individuals identified with the field as a whole as well as with one or more sub-fields including field, behavioral, and disease ecology. The associated sub-disciplines included many of those

previously listed with the addition of education, bioinformatics, and geography. The EEID participants represented a wide array of scientific disciplines, and therefore a number of disciplinary social worlds.

I proceeded with describing a selection of the identified associated disciplines. This process enabled me to determine potential categories of similarities and differences between the disciplines and to demonstrate that each field represented a distinct social world. I determined the categories of disciplinary identity characteristics by analyzing coding data from the disciplinary identity section of the interview protocol. A total of five disciplines were represented in the interview data and were therefore included in this analysis. These disciplines were mathematics, biology, ecology, molecular biology, and microbiology. A total of 10 participants identified with at least one of these fields as a primary discipline. Therefore, the following analysis represented the majority of participants involved in the EEID proposal development.

As demonstrated in Appendix C, I asked the following questions in the disciplinary identity section of the interview:

- What scientific discipline do you currently associate with? Is there more than one?
- What professional position(s) and associations do you currently hold? Are these positions limited to academia, or include industry as well?
- What distinctive features, such as methods, values, or writing styles come to mind when you think about your discipline?
- In your discipline, what does success mean? What does success mean to you?
- How do you fit into your discipline, and how do you differ from other people in your discipline?

- Reflecting on what we just talked about, how do you think you and your discipline differ from your teammates working on the EEID grant?
- Do you think that these differences stem from the fact that you each come from a different scientific discipline?

I coded the responses to these lines of inquiry by question and then grouped codes across the disciplinary identity section. The results are presented in Table 6 with the number of participants who mentioned each code.

Table 6. *Identified codes and the number of participants who mentioned each code in the disciplinary identity section of the interview*

Codes	Number of Participants
Disciplinary modes of thinking / research methods	4
Disciplinary knowledge base	2
Motivation to perform work	5
Discipline's attitude towards interdisciplinarity	4
Disciplinary writing style and language	2
Disciplinary training	4
Disciplinary measures of success	5
Priorities in proposal development	3
Collaborative process	2

The codes listed above represented categories of disciplinary characteristics perceived by each interviewee. In general, all responses were focused around these codes and the respondents provided information on how their respective disciplines were characterized under each code. The driving motivations behind doing work, a discipline's impact on making interdisciplinary

work possible, training, and measures of success featured prominently in the interview responses. Disciplinary modes of thinking and research methods were also addressed by four of the five interviewees. In contrast, only two participants discussed disciplinary knowledge base. This did not necessarily signify this code's lack of importance in describing disciplinary identity. Instead, different topics of study and therefore knowledge bases are commonly understood as defining characteristics of a discipline. The respondents may have felt it unnecessary to mention this factor, thus leading to a low reporting rate. Along a similar vein, the code that described disciplinary writing style and language was only mentioned by two of the five interviewees, but is commonly understood as a significant difference between disciplines. The final two codes, priorities in proposal development and collaborative process, were worth mentioning. These two disciplinary factors could significantly differ between participants and necessitate negotiation. However, analysis of these codes falls outside the scope of the current study and can be addressed in future research. In all, these codes represented prominent and ubiquitous factors that were the foundation of scientific disciplinary identity.

These codes became particularly useful when describing the five scientific disciplines of interest. Defining disciplines was a challenging prospect because these fields are in constant flux, changing character with the demands of society and blurring boundaries with other fields. However, using the codes described above allowed me to create a framework for my analysis. I was able to effectively focus my discipline descriptions on specific and significant characteristics.

Although all of the codes were important, I only selected five for this analysis in order to maintain the scope of the study and provide a description of disciplinary identity relevant to this study context. Specifically, I framed my description of each discipline using five codes from

Table 6 including knowledge base, modes of thinking and research methods, motivation to do work and measures of success, writing style and language, and attitude towards interdisciplinarity. I substantiated the following disciplinary descriptions with interview coding data, demographic research, textual analysis, and literature reviews. Comparison of the resulting descriptions revealed the differences and similarities between scientific disciplines within this study and therefore suggested disciplinary factors that required negotiation between collaborators in the development of the EEID proposal.

Mathematics: Knowledge base. The discipline of mathematics encompasses a broad range of study areas and is therefore exceedingly difficult to define. The American Heritage Dictionary (2011) offers a broad definition: “The study of the measurement, properties, and relationships of quantities and sets, using numbers and symbols” (“Mathematical Discipline,” 2011). However, this definition is inadequate as it does not scratch the surface of this discipline’s complexity. Robert Mura, a Canadian researcher, surveyed mathematics educators and mathematicians to collect their definitions of the field. Many participants responded that it was too difficult, impossible or futile to define the field. Others however, offered an array of descriptions (Mura, 1993, 1995). In summary, Mura (1995) writes,

The two images of mathematics as a formal abstract system ruled by logic and as a model of the real world are both quite widespread. Mathematics is also considered to be both an art and a science, both a language, i.e. a form, and a set of specific contents. (p. 394)

The modern discipline of mathematics can be broken down into two primary and related components, applied and pure mathematics. Pure mathematics is the study of abstract concepts, objects and structures using inductive and deductive reasoning. The study revolves around the idea of generalizability of findings and thus claims to create the foundation of all mathematics (Mura, 1995; Obeng-Denteh & Amoah-Mensah, 2011). This study and the development of

theorems are done for their own sake, and may or may not be applied to a “real-world” problem later on (Obeng-Denteh & Amoah-Mensah, 2011). This division of mathematics includes fields of study such as algebra, geometry, logic, and number theory.

Applied mathematics is the study of applying methods to examine physical phenomena and practical problems (Obeng-Denteh & Amoah-Mensah, 2011). Numbers and symbols act as a common language used across the sciences, business, and industry to create, analyze, and apply models that represent reality and thus provide a “means of understanding phenomena and making predictions” (Mura, 1995, p. 389). Pure and applied mathematics work in tandem, the former informing the latter.

The EEID team included three individuals, Shandu, Simon and Anne, who identified with the mathematical discipline. Their areas of expertise represented both pure and applied fields. Shandu’s focus area was in the field of differential equations, both in terms of their pure analysis and in their applications to cosmology, astrophysics, epidemiology and cancer modeling. Simon and Anne focused their research on one or more areas that included the application of statistical analyses, mathematical modeling and computer simulation of infectious disease. The mathematicians’ contributions to the EEID proposal effort fell under applied mathematics in the form of using a mathematical model to examine the system of tick-borne disease.

Mathematics: Modes of thinking and research methods. The mathematical discipline, as it pertained to this study, was further defined by the collaborators’ modes of thinking and general approach to research. Anne described her discipline as more theoretical and abstract compared to others:

Mathematicians use a general rule and a different wavelength in a lot of ways, they have to have the ability to focus and think about things in much more theoretical terms, and are more able to abstract. Biologists are much better, in general, at the concrete ability of teasing things apart and understanding the nuance of the fine dynamics of things, is what

I have experienced. So, I think they are both pattern seekers, they just seek patterns from very different angles. (Anne, interview, October 15, 2014)

This mode of thinking was expected considering the theoretical and abstract nature of the topics of mathematical study. Along a similar vein, Anne made the observation that mathematics was less detailed in its methodologies and in observations of a system compared to other scientific disciplines. This aligned with the concept mentioned earlier about the focus of mathematics on generalizability and using numbers and symbols to represent reality. Instead of focusing on the act of teasing apart and identifying every fundamental component of a system, mathematicians tend to work in the opposite direction. In the case of the EEID proposal, the mathematicians sought to compile different components of an ecological system and represent that system through mathematical modeling. Thus, in order to achieve these outcomes, mathematical methods and observations moved away from detail towards generality.

Mathematics: Motivation to work and measures of success. Factors such as motivation to perform work and measures of success differ between scientific disciplines. Leone Burton (2009), an expert in mathematical education, describes the mathematical discipline as one that is imbued with a culture of competition and hierarchy. Therefore, significant value is placed on professional position and research accomplishments. Burton's (2009) observations support Anne's experience in the field. She remarked that a mathematician's primary motivation to work was driven by his or her desire to promote up the professional hierarchy, specifically to attain tenure. Additional motivators and measures of success included the number and quality of publications as well as the achievements of your students (Anne, interview, October 15, 2014).

Mathematics: Writing styles and language. The mathematical discipline has its own genre knowledge. As such, mathematicians use specific writing styles and language to communicate with each other and represent their research to specific audiences. In general,

mathematical texts are written in a concise and unambiguous style. In addition, these texts often incorporate numerous numbers and symbols to demonstrate proofs and theorems. This mathematical language is often not fully understood by other disciplines due to the extremely technical nature of the content.

Mathematics: Attitude towards interdisciplinarity. The final code for disciplinary identity was the field's attitude towards interdisciplinarity. Mathematicians in applied fields are inherently interdisciplinary and engaged with different disciplines in order to implement their knowledge. Therefore, mathematics is often referred to as the universal language, used by every human being and by every scientific discipline. Even though this level of interdisciplinarity exists, mathematicians generally preserve a focused disciplinary identity. They remain pure to their primary discipline due to cultural structures and restrictions, such as accepted training paths and discipline specific promotion milestones. Anne had first-hand experience with this scenario through her identification with both mathematics and biology. She touched on the challenges of achieving tenure when in this position. Specifically, if an individual attempts to bridge two disciplines, mathematics is less likely to recognize or translate that individual's accomplishments into the achievement of professional milestones, which results in a lack of promotion and success (Anne, interview, October 15, 2014). Although mathematicians faithfully identify with their field, their knowledge is used across all facets of science. Therefore, mathematics accepts and pursues interdisciplinarity.

Biology: Knowledge base. Similar to mathematics, the discipline of biology cannot be concisely defined, but in a broad sense, biology is the study of life on different scales of size and time (Campbell, 1996). The scope of biology is too large for an individual to effectively study and master. Therefore, the discipline is divided into numerous fields that each specialize in

specific topics and have a more focused scope. Examples of these specialized biological disciplines are examined below and include ecology, molecular biology, and microbiology.

Biology: Modes of thinking and research methods; motivation to work and measures of success; language and writing styles; attitudes toward interdisciplinarity. Due to the broad scope and inclusion of specialized disciplines, the field of biology encompasses numerous modes of thinking and research methods. All of the remaining disciplinary identity codes of motivation to work and measures of success, language and writing styles, and attitude towards interdisciplinarity are equally as diverse and dependent upon the specialized discipline.

Interestingly, Anne identified with biology as a primary discipline as opposed to a more specialized field. Anne's research efforts focused primarily in the specialized disciplines of ecology and epidemiology, and were growing into molecular biology. For Anne, identifying with biology as opposed to a more specialized field appeared to be a strategic choice that better suited her needs and interests. Associating with biology enabled her to avoid disciplinary confinement. This enhanced her access to research opportunities and methods through growth into multiple disciplines within biology and mathematics.

Ecology: Knowledge base. The Ecological Society of America (2015) defines their field as "the study of the relationships between living organisms, including humans, and their physical environment; it seeks to understand the vital connections between plants and animals and the world around them" ("What Does Ecology Have to Do with Me?," 2015). Topics of study range in the type and number of organisms, as well as the environments studied. Examples include examining bacteria in a petri dish or the study of numerous plants and animals interacting in a rainforest or ocean ecosystem. Due to the breadth of study options, ecologists often focus their efforts into sub-branches of the field.

Three participants in this study, Jim, Jen, and Matt, identified with ecology as their primary discipline. Jim offered valuable input in defining this discipline's topics of study and knowledge base through his interview responses. Specifically, Jim focused his research in behavioral ecology, which was the study of how environmental pressures and natural selection influenced animal behavior and in turn, how adaptation impacted survivability and reproductive success (G. Johnson & Raven, 2001). Within this branch of ecology, Jim researched a specific bird species and its breeding systems, interactions with man-made structures, and how different species transferred pathogens (Jim, interview, October 10, 2014).

The remaining two ecology participants, Jen and Matt, focused much of their efforts in disease ecology. Disease ecology is described as follows:

The ecological study of host-pathogen interactions within the context of their environment and evolution... At the foundation of disease ecology are efforts to understand pathogen transmission and spread over space and time and impacts on host populations. These goals differ from those of related fields such as parasitology, which focuses on parasite taxonomy and life cycles, and epidemiology, which aims to identify risk factors for infectious and non-infectious diseases. (Kilpatrick & Altizer, 2010, p. 55)

Jen focused her research efforts on Dengue, Malaria, and tick-borne diseases. She examined how they spread and impacted hosts in response to landscape change, climate change, and health outcomes. Matt's recent research was focused on examining Lyme disease and its spread through different hosts.

Ecology: Modes of thinking and research methods. In order to conduct research on the topics described above, the field of ecology has adopted distinct modes of thinking and methodologies. Jim offered significant insight into these factors, which reinforced my own experiences conducting research in the field. Due to the focus on how organisms and the environment interact, ecology's mode of thinking is based on systems. Independent of the topic, all ecologists examine how multiple components of an environmental system interact to produce

specific outcomes for the organism(s) under study. Ecologists tend towards identifying systems, teasing apart components, deducing relationships and causality, and dealing with uncertainty due to confounding variables. These modes of thinking and the nature of ecological study topics impact the field's methods for research. Specifically, the focus on environmental systems reduces an ecologist's ability to conduct research entirely within a laboratory. Therefore, ecological methods tend to include measurement / sampling based methodologies that occur in the field as well as computer modeling (Henderson, 2001). These methods enable a researcher to understand his or her organism of study in their current environmental system. In summary, two participants, Jim and Mike, stated that ecology and its methodologies are focused on understanding how systems function as a whole (Jim, interview, October 10, 2014; Mike, interview, October 23, 2014).

Ecology: Motivation to work and measures of success. Ecologists conduct the work cited above for a variety of reasons. During Jim's interview, he described ecology as a way of life that was seeded in a deep connection with nature and passion for conservation of wildlife, the environment and its health. He contrasted other disciplines against his own, describing them as more technical and "business-like." Jim suggested that the primary motivation for ecologists to conduct research stemmed from an idealistic goal and life-long calling to preserve wildlife and the natural environment (Jim, interview, October 10, 2014). Measures of success in ecology included attaining funding for this research, publishing, and maintaining a good reputation amongst one's employer, collaborators, and the field.

Ecology: Writing styles and language. The ecological discipline, like others, possesses its own genre knowledge. Ecologists use writing styles and language appropriate to their field, including Latin naming practices for organisms and unique methodological terms.

Ecology: Attitude towards interdisciplinarity. The disciplinary identity code of attitude towards interdisciplinarity was also addressed during Jim's interview. In general, ecology was open to interdisciplinary collaboration due to the systems approach taken by the field. In the case of the EEID proposal, the ecology collaborators sought to understand the components of a tick-borne disease system. Therefore, they needed to consider climate, geographical, ecological, molecular and other biological factors. This forced ecologists within the EEID team and those at large, to consult with other disciplines to gain a greater depth of knowledge pertaining to the specific system under study. Therefore, the field of ecology is generally accepting of and can effectively perform interdisciplinary work.

Molecular biology: Knowledge base. The field of molecular biology primarily examines biological activity between cellular systems at the molecular level. Michael Cox, Jennifer Doudna, and Michael O'Donnell are all accomplished researchers in the fields of biochemistry and molecular biology. These scientists offer a definition of molecular biology:

Broadly speaking, molecular biology is the study of essential cellular macromolecules, including DNA [deoxyribonucleic acid], RNA [ribonucleic acid], and proteins, and the biological pathways between them. Over the decades, molecular biology has become firmly associated with the structure, function, and regulation of information pathways at the molecular level. (Cox, Doudna, & O'Donnell, 2012, p. 2)

These information pathways take the form of the replication and transcription of genetic material into RNA, subsequent translation into proteins, and surrounding cellular functions. Two of the participants interviewed, Mike and Amir, identified with molecular biology as their primary discipline. Mike's research was focused on characterizing how a specific disease impacted a species of marine fish. Amir's research was directed towards researching tick salivary proteins and host immune responses.

Molecular biology: Modes of thinking and research methods. When asked to describe his discipline, Mike offered insight into molecular biologists' mode of thinking by stating that they are "very reductionist. Everything tends to get broken down into its parts, when we try to understand a system, we really try to break it down to its individual genes" (Mike, interview, October 23, 2014). The methodological approaches mirror this intent and further define molecular biology as a discipline.

Specific experimental methodologies are crucial to a molecular biologist and comprise a significant amount of their foundational knowledge. Unlike ecology or biology, only a selection of specific methods exists that allow a scientist to visualize, examine and quantify the microscopic components of a cell and their functions. The common techniques include molecular cloning, variants of polymerase chain reactions, gel electrophoresis, arrays, and others. These methods require significant training, practice and perfected technique to acquire accurate and viable results.

Molecular biologists depend on a finite list of techniques to gain knowledge. This dependency places constraints on these scientists, which has created two prominent modes of thinking within molecular biology. The first mode is that the research approach is generally technique driven as opposed to question driven. To illustrate this point, the abundance of available methods and observation tools in ecology enable researchers to design research questions based on environmental issues or other concerns. Once an issue is identified, ecologists can decide which methods are best suited to address that issue. In contrast, molecular biologists only have limited techniques that enable them to observe specific outcomes. Therefore, research aims are often decided upon based around the data that available techniques will produce.

The second mode of thinking places significant emphasis on methodological innovation. Novel techniques in molecular biology can result in vast discoveries by creating new ways to observe microscopic processes that are currently undetectable and therefore, unknown. Mike emphasized this point by stating,

Try to figure out what they used 10 years ago and figure out what they were doing two years ago, and then try to figure out what they are doing today, because one of the things about molecular, especially with next generation sequencing techniques, is basically by the time something is published, it is already obsolete. (Mike, interview, October 23, 2014)

In summary, the discipline of molecular biology is primarily focused on individual components of a greater system and mastering highly specialized techniques. This field is also methods driven and places great significance in methodological innovation.

Molecular biology: Motivation to work and measures of success. In order to conduct research in molecular biology, a scientist needs significant funding. The materials necessary to execute molecular methodologies, including instruments, chemicals, and disposables, are both extensive and expensive. Mike and Amir stressed that the driving motivation for molecular biologists remains an innate curiosity and passion for the topic, but the success of a molecular biologist is first and foremost, measured by money. The more funding a lab has, the more equipment it can purchase, the more techniques it can execute, and the more results it can produce. The success of a molecular biologist is also measured by the number and quality of his or her publications.

Molecular biology: Writing styles and language. As with each discipline described, molecular biology has its own genre knowledge and thus writing style and language. Discourse stemming from molecular biology can be challenging for an outsider to read due to specialized terminology and its highly technical nature. The discourse topics in molecular biology often

center on specific proteins and specialized pathways that are named by the author. In addition, the constant discovery and naming of new molecules and processes makes it nearly impossible for an outsider to keep abreast and thus understand what a molecular biology manuscript is even about. The same is true for the rapidly changing techniques used by molecular biologists. The specificity and constant changes in this field result in a highly specialized language used by molecular biologists.

Molecular biology: Attitude towards interdisciplinarity. Molecular biology is not defined by its involvement in interdisciplinary endeavors. Similar to pure mathematics, molecular biologists need not stray far from their own techniques and proteins due to the reductionist nature of their research. However, Mike stated in his interview, “this is becoming an era of systems biology where we realize that many things work in concert and that we have to understand how things connect, not just how things work in a vacuum” (Mike, interview, October 23, 2014). Thus, molecular biologists can break out and join collaborations to increase the breadth of expertise and inquiry into a particular system, or they can remain within the confines of molecular biology.

Microbiology: Knowledge base. The discipline of microbiology is concerned with the study of unicellular, multicellular, or acellular microorganisms that are very small, and only visible through a microscope (Vassanthakumari, 2007). Thus, microbiologists study organisms including bacteria, protozoa, parasites, viruses, algae, and fungi. They seek to understand the following:

microbial form and structure, the evolution of microbes including bacterial taxonomy, microbial reproduction and genetics, microbial metabolism, role of microbes in human illness, their distribution in the natural environment and the changes induced by the environment, microbial diversity and bioremediation, and exploitation of microbes for use in industrial processes. (Vassanthakumari, 2007, p. 3)

One participant, Craig, identified with microbiology as his primary discipline. Craig focused his research in the study of microbial infection as it related to the tick immune system and transmission to vertebrate hosts. He also investigated the properties of the organism *Streptococcus pyogenes*, and its establishment of infection and role in disease. Finally, Craig examined antibiotic resistance in microorganisms.

Microbiology: Modes of thinking and research methods. Microbiology and molecular biology follow a similar mode of thinking and methodological approach, which is often reductionist and technique driven. Mike confirmed this finding by stating that “[Craig] and I are pretty similar, he is a microbiologist and I am a molecular biologist, and we both do molecular biology next generation stuff. He and I approach questions from a pretty similar angle” (Mike, interview, October 23, 2014). The two fields share many experimental methodologies and their areas of study can overlap. However, microbiologists are more concerned with the microorganism itself as opposed to the molecular components and pathways of a higher multicellular organism.

Microbiology: Motivation to work and measures of success. Microbiology and molecular biology are also similar in their sources of motivation and measures of success. Since the two fields require expensive materials and equipment, securing funding is necessary. Craig confirmed this by stating that measures of success in microbiology were “publications and funding. The standard. That’s the only way we get jobs” (Craig, interview, October 9, 2014).

Microbiology: Writing styles and language. The similarities between these two fields also extend to their writing styles and language. As described earlier, the technical nature and naming practices used by microbiology and molecular biology lead to a highly specialized language often only understood by members of the field. There is enough overlap between these

two fields, that the terminology and styles are understood by both parties. Craig stated that his discipline

significantly differed from [Anne]'s. She is a mathematical biologist so the math stuff she does is totally different from the molecular biology stuff that I do. I have trained her to understand microbiology speak a little bit. She is still working with me to understand all of the squiggly lines and everything that the mathematicians use. But, there are distinct differences there.... That's one reason why we collaborate. (Craig, interview, October 9, 2014)

Craig's statement alluded to two important disciplinary characteristics. First, he interchanged molecular biology and microbiology, indicating that the two fields are closely aligned in their approach and techniques. In addition, he mentioned the communication gap between himself and Anne, emphasizing the real collaborative barrier presented by trying to cross communities.

Microbiology: Attitude towards interdisciplinarity. Microbiologists tend towards becoming more interdisciplinary themselves. Craig discussed the need to broaden the number and type of tools available to examine microbiology topics. The search for additional tools directed these scientists into other disciplines, as Craig explained:

Within microbiology, you are getting a lot more [people] into bioinformatics, heavy computing... it is interdisciplinary in some respects, but it is being able to use the tools that are available. There are some that are going more into the modeling component, again that is just making use of tools... They [new microbiology hires] have been much more cross-disciplinary in terms of their ability to use modern technology that is available rather than necessarily collaborating with someone different. (Craig, interview, October 9, 2014)

Thus, it appeared that microbiologists were motivated to increase their own knowledge base and available tools in related fields in addition to seeking out collaborations to address abilities that are too far outside their discipline.

Summary. The scientific disciplines described above could all be characterized by the five codes identified in the interview coding protocol. Each discipline had a unique set of qualities that comprised their knowledge bases, modes of thinking and research methods,

motivations and measures of success, writing styles and language, and attitudes toward interdisciplinarity. Table 7 summarizes the disciplinary identities of mathematics, biology, ecology, molecular biology, and microbiology.

Table 7. *Summary of disciplinary characteristics per identity code*

Disciplinary Identity Codes	Primary Disciplines				
	Mathematics	Biology	Ecology	Molecular Biology	Microbiology
Knowledge base	Represent reality using numbers, symbols	Study all life	Examine how organisms interact with environment	Study cell function at molecular level	Study micro-organisms
Mode of thinking / approach	Theoretical / abstract	Varied, more concrete	Concrete, focus on systems / big picture	Reductionist, technique driven	Reductionist, technique driven
Motivation / measure of success	Promotion, number and quality of publications	Varied depending on specialty	Preservation of nature / conservation, funding / publications, good reputation	Money, publications	Money, publications
Writing style / language	Numerous equations and proofs represented through symbols	Varied depending on specialty	Concise	Highly technical with specialized terminology	Highly technical with specialized terminology
Attitude towards Interdisc.	Yes – for applied math	Yes	Yes – to understand system	Yes, but with limitations	Yes, tend towards interdisc. individual

Table 7 demonstrates that a combination of similarities and distinct differences existed between each discipline studied. Therefore, each of these scientific disciplines represented a unique social world. The ability to characterize the disciplines by these codes and identify the differences between them emphasized the fact that the EEID proposal was intersected and developed by an interdisciplinary team.

4.5 CONCLUSIONS

Through the analyses described above, I demonstrated that the EEID proposal fulfilled the necessary boundary object criterion of intersecting multiple social worlds, to include academic institutions and associated scientific disciplines. This conclusion was supported by the detailed disciplinary identity analysis. Although I collected the data presented above from a small set of representative individuals situated in a specific context, these data accurately represented the perceived differences between the collaborators' disciplines and suggested factors that required negotiation through the EEID proposal.

The results from the disciplinary analysis achieved greater significance than expected. One of the more interesting realizations that I made during this study was the fact that the differences between scientific disciplines were often ambiguous to or completely unrealized by scientists. Between the EEID participants, some of the differing characteristics were readily realized such as knowledge bases and methodologies. However, specific modes of thinking, writing styles and attitudes towards interdisciplinarity were more subtle or misunderstood due to stereotyping. This observation was further emphasized by the agency review of the EEID proposal, which questioned the interdisciplinarity of the effort. Reviewer 4 stated that he was “not sure that the project is as interdisciplinary as claimed (there are a lot of biologists)”

(Reviewer 4, unpublished data, March 18, 2015). In addition, the summary of the reviewer comments lauded the team's expertise but criticized the "heavily biology focused" research (Review Summary, unpublished data, March 18, 2015). These responses suggested that both the EEID team members and the agency reviewers had limited awareness of the differences that existed between the involved disciplines, and assumed a high level of similarity between them.

This phenomenon was potentially caused by the way scientists are classified. The term 'science' refers to the "knowledge about or study of the natural world based on facts learned through experiments and observation" ("Science," 2015, p. n.p.). This term is an overarching label for numerous disciplines that all share common features including the study of natural phenomenon, use of the scientific method, and quest for replicable and valid findings. The common label and characteristics may provide individuals with a false sense of similarity and unity between the scientific disciplines.

Despite the 'science' classification, disciplines do have unique identities defined by specific bodies of knowledge, approaches, modes of inquiry, conventions, and language. I demonstrated that distinct differences existed between the EEID team member disciplines with respect to the five characterizing codes. In addition, the lack of awareness of these differences could lead to collaborative barriers and issues with agency reviews.

The first issue of unrealized differences between scientific disciplines can make collaborations hard to successfully execute. Interdisciplinary work requires time, practice, and an investment in the negotiation and resolution of differences in order to create a cohesive product (Lele & Norgaard, 2005; Morse et al., 2007). The more overt differences realized by scientists can still act as barriers to collaboration, but may be proactively negotiated due to increased awareness (Morse et al., 2007). However, the more subtle differences that remain

unrealized can be a significant source for conflict and confusion. Collaborators may not know that a negotiation is necessary, why one is taking place, and/or what is being negotiated. This lack of awareness and direction may result in a decreased occurrence of resolution and productivity in a collaboration.

The second issue that became apparent during this study was that a common definition of the term ‘interdisciplinary’ did not exist between the collaborators and the agency. During his interview, Craig foretold this issue:

It depends on the definition of interdisciplinarity because some people say that what [Anne] and I do is not interdisciplinary. We are both in biology, we are both dealing with biological problems. Some people would not consider that interdisciplinary, whereas I do. (Craig, interview, October 9, 2014)

This lack of definition was problematic as the EEID team understood themselves to be interdisciplinary. However, their disciplinary composition did not satisfy the NSF reviewer, thus hindering access to funding. This outcome demonstrated the need for a universally understood and adhered to definition of interdisciplinary in order to normalize the review process.

Describing disciplines through the five identity codes of knowledge base, modes of thinking and research approach, motivation to work and measures of success, writing styles and language, and attitudes towards interdisciplinarity provides a definitive method to identify distinct differences between disciplines. This identification process is significant for two reasons. First, the method increases awareness of potential collaborative barriers and sites for negotiation. Second, this process may offer a foundation for defining interdisciplinarity through the assessed degrees of difference between disciplines. With respect to the EEID team, the differences between ecology, molecular biology and biology could then be presented to the NSF to prove a necessary degree of interdisciplinarity. In turn, the NSF could use these identity

categories to enforce a standard definition of interdisciplinarity for reviewers, thus reducing subjectivity in proposal assessment.

Scientific disciplines display a variety of unique characteristics, whether realized or not. The differences in these characteristics are a significant cause for negotiation. The following chapters expand upon the initial findings, conclusions, and issues presented here.

CHAPTER 5

EEID PROPOSAL BOUNDARY OBJECT DESCRIPTION:

SATISFYING INFORMATIONAL REQUIREMENTS

My initial analysis of the Ecology and Evolution of Infectious Disease (EEID) proposal boundary object in Chapter 4 offered insight into the defining characteristics of the involved social worlds, particularly with respect to scientific disciplines. I identified five factors that significantly contributed to disciplinary identity and were potential sources for negotiation through the EEID proposal. Even though this social world analysis was fruitful, I needed to conduct additional analyses to understand the proposal itself and more specifically, what aspects of the proposal enabled negotiation. Within this chapter, I discuss how the EEID proposal, as a member of the research proposal genre, fulfills the additional boundary object criterion of satisfying informational requirements in each of the involved social worlds. To qualify, proposals must uphold a common identity, but also contain plastic elements that can be shaped according to specific disciplinary needs. In this analysis, I identify both the common and plastic elements of proposals and suggest potential sites for the negotiation of disciplinary identity. I broaden the discussion of mediating factors on proposal development by situating the EEID proposal in a greater genre ecology and social world context.

5.1 SATISFYING INFORMATIONAL REQUIREMENTS

In the following sections, I discuss the common and plastic features of the research proposal genre and how the EEID proposal in particular, satisfies the informational requirements of the scientific disciplines involved in this study.

5.1.1 Common identity of the research proposal genre. Multiple scholars have performed genre analyses on the research proposal. These scholars have delineated a common identity of this genre that is comprised of a singular communicative purpose and pervasive rhetorical strategies (Connor, 2000; Connor & Mauranen, 1999; Feng & Shi, 2004; Myers, 1985, 1990). Greg Myers was one of these scholars and he specialized in the study of the social context surrounding scientific texts. Myers (1985) initiated the study of proposals by examining the major sequential drafts of two federal research proposals in the biological sciences. Myers (1985) wrote,

In classical rhetorical terms, the forms of appeal in the proposal are ethical and pathetic as well as logical; one shows that one is able to do the work, and that the work is potentially interesting to one's audience of other researchers, as well as showing that one is right. In textual terms, one describes the work so as to create a persona and insert the work into the existing body of literature. (p. 220)

Myers' (1985) work offered insight into not only the rhetorical purpose of proposals, but also the constraints and challenges of the genre. He suggested that proposal writers were required to demonstrate the originality and superiority of their work. However, the demonstration had to be in a format and persona that closely aligned the work to the concerns of the funding agency and greater research community (Myers, 1985). Myers' findings suggested that research proposals had the universal communicative purpose of persuading funding through common rhetorical strategies, while the persona and format could be manipulated to align with a specific discipline or funding agency.

Myers' (1985) observations were expanded upon in research conducted by Ulla Connor and Anna Mauranen (1999). These researchers used a linguistic/rhetorical approach to identify 'moves' that represented functional components specific to a genre or discourse and had a particular rhetorical purpose. Connor and Mauranen (1999) examined 32 federal research

proposals from multiple scientific disciplines and identified 10 moves. These moves included territory, or how the research was situated in a greater picture; the gap in knowledge; the goal or objective of the study; the means by which the goal was achieved; previous research; benefits of study outcomes; competence of the research members; the importance of the research; and the compliance or relevance of the research to agency objectives (Connor, 2000; Connor & Mauranen, 1999). These moves defined the functional components inherent in a proposal that were used to persuade the reviewing agency to award funding.

Connor (2000) continued her research by examining 14 research proposals written by five writers spanning both humanities and scientific disciplines. She determined that four rhetorical moves, including territory, gap, goal, and means occurred in all of the proposals, regardless of discipline (Connor, 2000). These findings suggested that these specific rhetorical strategies formed the common identity of a research proposal across scientific disciplines. Haiying Feng, a Chinese researcher in rhetoric and discourse analysis, and Ling Shi, an expert in English as a Second Language (ESL), augmented these findings. They conducted a similar genre analysis of the summaries of nine federally funded research proposals from the social sciences and humanities. These researchers also used the “move” analysis in order to identify and interpret the regularities of organization in the document and to determine the rhetorical patterns and strategies that the writers used to create a funded proposal (Feng & Shi, 2004). Feng and Shi (2004) summarized the generic structure of proposal summaries in three moves including justifying the research need, describing the means to meet the research need, and creating a claim of potential contributions made by the proposed study (p. 14).

According to the analyses discussed above, the research proposal genre has a common identity across multiple disciplines. Therefore, this genre fulfills the first aspect of the boundary

object criterion for satisfying informational requirements across social worlds. The first pervasive element in proposals is the singular communicative purpose of persuading an agency to fund research. In addition, all research proposals share common rhetorical strategies. The first strategy is the justification of research need through the delineation of territory and a gap in knowledge. This justification is dependent upon the comprehensive understanding and presentation of relevant disciplinary knowledge. The second strategy is a description of the means used to address the identified research need. This is accomplished through the presentation of concise goals as well as appropriate and feasible methods. The final strategy is the contributions claim, or an explanation of potential societal benefits from research outcomes (Connor, 2000; Connor & Mauranen, 1999; Feng & Shi, 2004). These findings are highly relevant and helped to frame my analysis of the common elements of the EEID proposal.

5.1.2 Common identity of the EEID proposal. The analyses conducted by Myers (1985), Connor and Maurenen (1999), Connor (2000), and Feng and Shi (2004) described the robust common identity of the research proposal genre with respect to purpose and rhetorical strategies. Using these studies as a framework, I examined the text and identified these characteristics in the EEID proposal, demonstrating that this document was part of the research proposal genre. Due to the proprietary nature of the EEID proposal contents, I depend upon paraphrasing proposal text and quoting interview responses to support my findings. In terms of the common communicative purpose, the EEID proposal was specifically written in response to a National Science Foundation (NSF) EEID program solicitation. The proposal identified a research need, described a research plan and developed a detailed budget for the sole purpose of requesting NSF funding for the proposed work. The communicative purpose of the EEID

proposal was well understood by the participants who were interviewed, regardless of discipline. As discussed in Chapter 4, the five interviewees represented the scientific disciplines of mathematics, biology, ecology, microbiology, and molecular biology. Even though these individuals identified with different scientific disciplines, they were all intimately familiar with the research proposal genre, having completed multiple proposals over their respective careers. When I asked them to describe what motivated them to participate in EEID proposal development, they universally responded that this proposal was a way to gain funding for their research. Anne, the Principal Investigator (PI) for the effort, emphasized this purpose:

Obviously we need money for the lab. It [the EEID Proposal] is the one shot we have for getting funding for this type of work. So, for me personally, this grant is exactly what I do, so it makes a lot of sense to apply. (Anne, interview, October 15, 2014)

The remaining interviewees referred to funding their collaborative work or simply exclaimed “money!” These responses further validated the communicative purpose of the EEID proposal, thus demonstrating that it shared this common characteristic with the research proposal genre.

The EEID proposal also contained all of the common rhetorical strategy characteristics including a justification of research need, a description of the means, and a contributions claim. The team conveyed the research need by situating their proposed work in both a relevant research territory as well as a real-world scenario using specific disciplinary knowledge. This rhetorical strategy was prominent in the *Introduction/Rationale* section of the project description and was achieved by introducing the current state of research concerning tick-borne diseases and the risk these pose to human and animal health. According to the authors, the prevalence of tick-borne diseases is on the rise worldwide, thus driving the need for additional research in order to enhance prevention capabilities. The need for the proposed research was further emphasized

through the identification of a gap in knowledge. This gap involved a lack of understanding of the reasons for this increased disease prevalence.

The authors performed additional rhetorical action in the EEID proposal by clearly describing the goal and means of the study. The researchers stated that they aimed to “understand the ecology of tick-borne... pathogens.” To accomplish this goal, the authors proposed a series of detailed methods pertaining to transmission, molecular, field, and mathematical modeling studies. These detailed descriptions, with the incorporation of preliminary data, demonstrated the viability of the approach and ensured the reviewer that the methodology was not only feasible, but would be successful as well.

Finally, the authors discussed the contributions of their study in the *Anticipated Results and Broader Impacts* section of the EEID proposal. The authors stated that “the results of this study will provide key public health information about when and where to expect the highest risks of TBD [tick-borne disease]” (EEID Proposal, unpublished data, November 19, 2014). Additionally, the authors suggested that “we will also engage students in cutting edge research with the goal of improving the STEM [Science, Technology, Engineering, and Math] talent pool graduating from all institutions working together on this project” (EEID Proposal, unpublished data, November 19, 2014).

The EEID team members, representing different social worlds, had proposal genre knowledge and were readily familiar with the common communicative purpose and rhetorical strategies of the research proposal genre. The EEID proposal reflected this understanding by containing each of the common rhetorical strategies. Thus, this proposal, like the genre at large, fulfilled the necessary boundary object criterion of satisfying common informational requirements across social worlds. This robust common identity enabled the researchers from

different disciplines to recognize the document and productively collaborate in its development. Although this commonality existed, each participant's genre knowledge was generally limited to his or her discipline-based understanding of a proposal, from the elements of the document itself to the components and impacts of the entire funding system. This limitation results in differences between each collaborator in how they approach and develop a research proposal, and restricts his or her understanding of other proposal subgenres. The plasticity of this genre accommodates these differences and allows for their negotiation during collaborative development, as discussed below.

5.1.3 Plasticity of the research proposal genre. In contrast to the common identity discussed above, boundary objects also have to be “plastic enough to adapt to local needs and the constraints of the several parties employing them... and become strongly structured in individual-site use” (Star & Griesemer, 1989, p. 393). Although the primary communicative purpose of the research proposal does not change between social worlds, the rhetorical strategies must be adapted, expanded upon, and formalized per disciplinary need in order to create a persuasive document. The adaptability of this genre has been demonstrated by the development of proposal subgenres that embody genre knowledge specific to a discipline, resulting in highly persuasive proposals. The plasticity of the research proposal genre is the reason it can be productively used by an interdisciplinary collaboration.

The plasticity of the EEID proposal was revealed during the interview protocol and through my analysis of the proposal text. I gained specific insight into the disciplinary differences that impact the development of rhetorical strategies within the research proposal by asking the interviewees the following questions (Appendix C):

- What parts of the EEID proposal do you plan on contributing to the most?
- What factors do you think are most important in developing the EEID proposal?
- What factors are most important to consider in designing the methods for the EEID proposal?
- Do you have specific methodologies or an approach in mind?

I examined the resulting codes and themes from this query and identified three primary rhetorical strategies used by the participants in EEID proposal development. These strategies included research need, means, and competence. The need and means strategies aligned with those from the common identity section, further verifying my previous findings. In addition, I identified a selection of secondary rhetorical strategies that participants used to develop and support the primary strategies. Of note, the rhetorical strategies that I identified in this study closely aligned to those described by Connor and Maurenen (1999), Connor (2000), and Feng and Shi (2004). This outcome also added validity to my interview data. Table 8 summarizes the codes determined in the interview protocol.

Table 8. *Identified rhetorical strategies in proposal development, N=number of interviewees who mentioned secondary strategy*

Primary Rhetorical Strategies	Secondary Rhetorical Strategies	Discipline
Research Need	Significant need in field	N=2; Ecology and Molecular Biology
	Applicable to important question	N=4; Ecology, Molecular Biology, Microbiology
Means	Methods established in discipline and literature	N=4; Mathematics/Biology, Molecular Biology, Microbiology
	Recent and innovative methods	N=3; Ecology, Molecular Biology
	Best fit to research question	N=2; Molecular Biology, Microbiology
Competence	Expertise and capability through past experience	N=3; Mathematics/Biology, Ecology, Microbiology

When I asked what factors were most important in developing the EEID proposal and methods, the interviewees were in consensus with respect to the primary rhetorical goal of the proposal. Each individual articulated that the proposal and all of its contents had to be relevant to the agency's needs and requirements. Anne emphasized this point:

You have to target your proposal for that agency and for that mechanism.... It's like when you are writing a cover letter to go with your resume for a job. If you don't know who you are applying to, you will write the wrong cover letter. (Anne, interview, October 15, 2014)

Although all of the interviewees agreed on addressing agency needs, the rhetorical strategies used to do this varied in content, type, and priority between the participants.

Specifically, four of the five interviewees discussed the rhetorical strategy of articulating the research need. Although this strategy was part of the robust common identity of the genre, the actual composition of the research need was plastic. Defining a need that aligned with agency priorities was dependent upon relevant and specialized disciplinary knowledge. Thus, the content used to express the research need was plastic and changed according to agency needs and the scientific disciplines involved. Additional plasticity in the strategy of research need was apparent in its prioritization compared to other strategies. Three of the four respondents, representing ecology, molecular biology, and microbiology, stressed that demonstrating the research need took priority over describing means, competence, and cohesion. This prioritization may not have been uniform among all team members, thus introducing a difference of opinion in how this strategy should have been emphasized in the proposal. The disciplinary knowledge used to develop the research need and its level of emphasis are plastic across the research proposal genre and dependent upon the specific composition and needs of the collaborating team.

The interviewees also addressed the rhetorical strategy of research means. Similar to research need, the content of a means strategy varied depending on agency priorities and the involved disciplines. For example, the overarching goal of the EEID proposal was to gain insight into the ecology of tick-borne pathogens. Jim, one of the ecologists on the team, approached this research goal at the multi-organism systems level. In contrast, Mike, a molecular biologist, was concerned with understanding the basic components of single cells. Thus, these disciplines addressed the research goal at very different levels and therefore offered significantly different methodological solutions. This example demonstrates the high level of plasticity inherent in the rhetorical strategy of research means with respect to content.

Plasticity was evident in the prioritization of the secondary strategies supporting the research means. Four of the five respondents suggested that the chosen methods had to be well established in their respective fields and in literature. This rhetorical strategy was used to convey the feasibility of the chosen methods and ensure their successful execution. Interestingly, this strategy took a back seat to the two additional strategies of demonstrating innovation and appropriateness of the methods to the research question. Three of the five participants suggested that demonstrating innovation in the methodological design was critical. Two of these individuals, representing ecology and molecular biology, prioritized innovation over all other strategies supporting research means. As discussed in Chapter 4, innovation is particularly valued in molecular biology due to the limited options and need for more methodologies. During one interview, Amir, a molecular biologist, expressed this disciplinary value:

If you are not innovating in your methodology, you will get nothing new... You have to tweak your methodology to get better results and I use the word tweaking, because this is also innovation... Something should be novel, otherwise it will not be a meritorious proposal. (Amir, interview, October 28, 2014)

In contrast to Amir's sentiment, one other participant, representing microbiology, believed that the strategy of demonstrating that the chosen methods were the best fit to the research question took priority over all other strategies supporting the research means. This prioritization makes sense for a microbiologist because the field is technique driven and each method produces specific types of data. The researcher must therefore ensure that this data appropriately informs the issue at hand.

Although all participants concurred that the rhetorical strategy of research means took priority just behind research need, differences in the importance placed on secondary rhetorical strategies existed between demonstrating the establishment of methods, innovation, and

appropriateness. This variation in content and priority demonstrated the plasticity inherent in these primary and secondary rhetorical strategies.

The final primary rhetorical strategy that I derived from the interview data involved the demonstration of competence. Three of the five interviewees suggested that a researcher had to convince the agency that they were clearly capable of executing the proposed methods. This was accomplished by demonstrating both their expertise and previous success in executing the same or similar methodologies. Jim described this scenario during his interview:

I want to make sure I can demonstrate that I can do the work, the collaborators I have with me can do the work, and that we are the best qualified in the world to do this work... What we propose has to have a proven track record with pilot data or we have this proof of concept that shows we can actually do the work. (Jim, interview, October 10, 2014)

Anne echoed this sentiment with the following statement:

It has to be a very well established methodology, so it needs to be something published on by you or another group, and you have to be able to demonstrate that you have the capacity to perform these methods effectively or you're not going to get funded. (Anne, interview, October 15, 2014)

Jim and Anne emphasized the need to demonstrate competence in a research proposal. The way in which this demonstration was accomplished however, was plastic and dependent upon the previous delineation of the research means. Specifically, the goals and chosen methods of the proposal influenced whose pilot data and past experience were used to demonstrate competence. Again, the competence claim can change across the research proposal genre according to specific agency and disciplinary needs.

This analysis demonstrates that the research proposal genre accommodates disciplinary differences and can be shaped according to local needs and constraints. This genre, and the EEID proposal specifically, therefore fulfill the boundary object criteria of informational plasticity. Through the interview analysis, I identified multiple plastic elements of the research

proposal genre. These elements consisted of primary and secondary rhetorical strategies. Each participant demonstrated a different understanding of these strategies in their content and priority. This outcome suggests that these elements differ between disciplinary proposal subgenres and are based on situated genre knowledge. Therefore, when different disciplines collaborate, the plastic elements of the proposal not only provide a site for, but also necessitate the negotiation of genre knowledge.

5.2 CONTEXT OF THE EEID PROPOSAL

The research proposal genre and specifically, the EEID proposal, did not occur in a vacuum but were part of a larger, more intricate system. I use the following discussion to provide some context for the EEID proposal and its development outside of the collaborative team members. In addition, I seek to further emphasize the complexity of the intersecting social worlds, their informational requirements, and to suggest a potential system of genres as boundary objects.

The application of Clay Spinuzzi's concept of genre ecology to my research was particularly useful and offered insight into the context surrounding research proposals (Spinuzzi, 2002, 2003, 2004). The genre ecology concept enables a researcher to examine a system of genres and describe how they mediate each other, interact with agents, and how genres change and stabilize over time. In addition, this framework does not take a hierarchical approach to genre systems, but instead has a community or cyclical viewpoint as mediation is rarely a top-down process (Spinuzzi, 2002).

The genre ecology framework was directly applicable to the EEID proposal and its development. This framework provided a context for the proposal and demonstrated the intricate

system of genres in which the document was placed. These genres, as discussed in Chapter 2, also acted as boundary objects because they intersected numerous social worlds throughout the funding system.

To create the EEID proposal genre ecology, as depicted in Figure 1, I collected data from meeting observations, interviews, emails, and the NSF website. This genre ecology demonstrated the numerous and often competing influences that mediated the development of the proposal elements that were plastic. These influential factors included numerous other genres that acted as boundary objects, the collaborators' social worlds, and additional organizations such as the federal government, the NSF funding agency, regulatory agencies and the research institutions. In turn, the EEID proposal sent mediatory feedback to these connected boundary objects and social worlds.

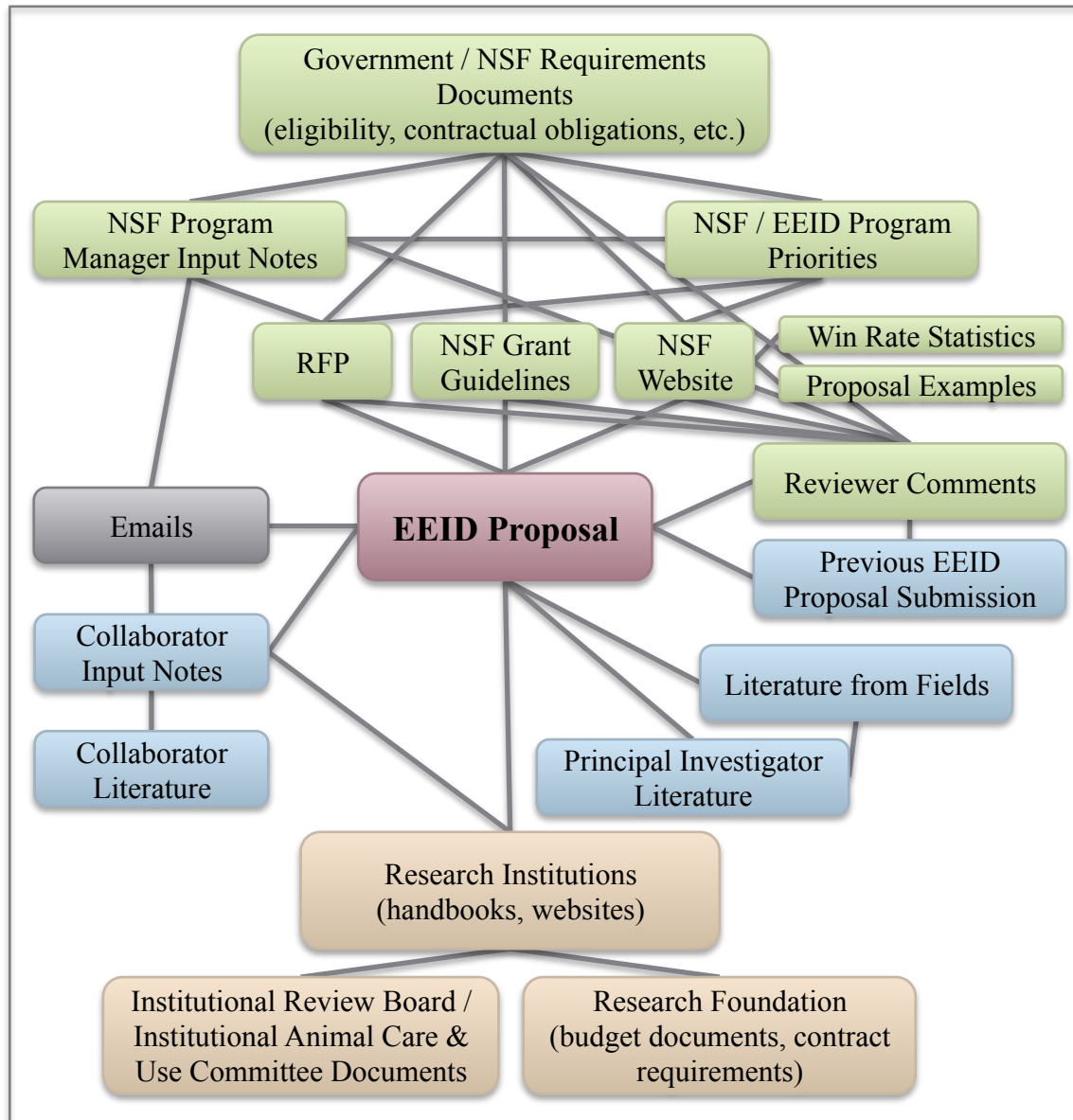


Figure 1: Genre ecology of NSF proposal development.

Although numerous connected genres were involved with the EEID proposal, three featured prominently in the interview and meeting data. These genres included the RFP, program priorities, and reviewer comments. These three genres formed the foundational

guidance for proposal development and dictated how the collaborators responded to agency needs. During one interview, Anne stated,

I certainly think you have to read the call for proposals because that gives you all of the terms and concepts that the granting agency wants to have... you have to target your proposal for that agency and for that mechanism. It should increase your chances of at least getting read. (Anne, interview, October 15, 2014)

The RFP provided significant guidance in writing the proposal with respect to the sections required, a program overview, and review criteria. In Anne's mind, the EEID proposal had to address and meet the RFP criteria as well as match the program priorities. Therefore, these two genres played a significant role in dictating the content, style, and structure of the EEID proposal. Mike discussed this sentiment further:

I think one of the things I struggle with the most is figuring out what the individual program is looking for because I have developed a number of what I thought were very good grants that got excellent reviews, but it wasn't necessarily the type of work they wanted to fund so they were not going to fund it. In a lot of cases, the science almost doesn't matter, it's whether this question you're asking fits with the program manager. (Mike, interview, October 23, 2014)

Both Anne and Mike realized the importance of the RFP and program priorities in impacting proposal development. In addition, the collaborators frequently referred to reviewer comments that were received following the previous EEID submission. During an observed meeting, the collaborators referred to a reviewer comment that suggested the inclusion of a social science methodology. The collaborators discussed potential interview and survey strategies to meet the reviewer's desires, even though this angle was not cohesively in line with their original research goals (EEID Team, meeting, October 20, 2014). The reviewer comments spurred significant changes to the EEID proposal, primarily impacting the methodology.

Other genres, acting as boundary objects, impacted the EEID proposal beyond those discussed above. Additional NSF guidelines and material, institutional requirements, and

literature from each participating discipline also mediated the final product. To complicate matters further, the ecology depicted in Figure 1 is not comprehensive. This context was highly complex and involved multiple collaborators, reviewers, and a program manager who all embodied a unique combination of different social worlds, including disciplines, research institutions, and a variety of states and nations.

Scholars have attempted to analyze some of these additional complexities. Christine Tardy, from the University of Arizona, performs genre and discourse studies and focuses on Writing in the Disciplines (WID). In one study, Tardy (2003) provided a high-level overview of the genre system surrounding the production of NSF research proposals, with particular emphasis on the interactions between genres and communities. Through text analysis, proposal process observations, and interviews, Tardy (2003) determined that the proposal was a small part of a larger system of texts that spanned numerous communities. This scenario forced the PI to bridge numerous genres and participate in multiple discourse communities. In addition, this study emphasized the importance of specific genres including the agency mission statement, grant application, cited literature, grant writing guides, on-line submission portal, and reviews. In terms of discourse communities, Tardy (2003) determined that the program officers (manager), reviewers, institutional review board committees, academic institutions, the program office and funding agency were involved. Tardy (2003) determined that genre systems and social interactions acted as a scaffold to guide the PI through the work required to produce a final proposal product and obtain funding. In addition, continued participation in the system and associated social interactions were integral in building one's genre knowledge (Tardy, 2003).

Tardy's (2003) research emphasized the complexity of the genre ecology for research proposals that was proposed above (Figure 1) by discussing the involved discourse communities

and their connection with genres. This research was augmented by work performed by Ryan Moeller and David Christensen, whose research areas focus in technical discourse and human agency. These researchers examined the NSF system for research proposals using genre field analysis. This approach enabled them to map complex mediating interactions between genres and people. Specifically, this method “uncovers the multiple perspectives and interactions within genre assemblages to expose the various spheres of influence—technologies, power relations, generic considerations, and local political situations—that shape the genre in ways that often go unnoticed and undocumented” (Moeller & Christensen, 2010, p. 71). Moeller and Christensen (2010) examined the NSF website system and its genre components (genre-agents). They also studied the people involved in proposal development (player-agents). This research identified numerous genre-agents and player-agents within the proposal field. Their findings reflected the data discussed for the EEID proposal genre ecology and findings from Tardy (2003). Interestingly however, Moeller and Christensen (2010) discussed agency and the level of influence or impact specific agents and players had on other components of the system. The genre-agents of the *Grant Proposal Guide* and the *Proposal and Award Policies and Procedures Guide* proved to be the most influential and dominant genres. These documents directed the development of proposal text in form and function. The genres also molded research to fit NSF priorities. These guides directed the responses of proposal writers, reviewers, and program officers by providing rules for the writing and revision processes (Moeller & Christensen, 2010). Moeller and Christensen’s (2010) research not only mapped the numerous genre and human components of the proposal system, but also provided insight into the power that these components had in mediating others.

The genre ecology for the EEID proposal and associated discussion demonstrated the complex system of boundary objects and social worlds that surrounded the document. The numerous components involved in this system introduce significant variation of social world and genre input that necessitate negotiation. Although a detailed system analysis was not within the scope of this project, these additional boundary objects and social worlds offer a vast variety of opportunities for future research endeavors.

5.3 CONCLUSIONS

As demonstrated, the EEID proposal fulfilled all of the criteria of a boundary object and was just one piece in a complex system of additional objects and social worlds. More specifically however, the EEID proposal met the informational requirements criteria as it clearly retained the common identity characteristics of a research proposal across social worlds, but also had plastic elements that enabled each world to tailor the discourse to their specific needs.

The team recognized the common identity of the research proposal genre that is shared across all scientific disciplines. This enabled all team members to immediately understand the tasks and materials required for the proposal and thereby be productive members in its development. The plasticity of the research proposal genre made collaborative development possible, but more challenging. This study demonstrated that each discipline manipulated the plastic elements of the genre to incorporate specialized genre knowledge based on situated needs. This knowledge stemmed from each participant's understanding of a proposal subgenre and genre ecology based out of his or her own discipline. Therefore, each team member had a different understanding of the content that supports the plastic elements and the priority that these elements should have within a proposal. The plastic elements of the proposal necessitated

and offered a site for the negotiation of social differences, particularly with respect to disciplinary genre knowledge.

The EEID proposal was an intriguing example of a research proposal in that it was recognizable within its genre, but intersected multiple social worlds and therefore represented the integration of numerous subgenres. As a boundary object, this genre provided a nexus for the negotiation of specific and significant disciplinary differences, which is further examined in the next chapter. The integration of disciplinary characteristics in this boundary object also complicates our discipline-based definition and understanding of genre. This issue will be expanded upon in the conclusion of this study.

CHAPTER 6

EEID PROPOSAL BOUNDARY OBJECT DESCRIPTION:

NEGOTIATIONS TO PRODUCE ACTION

The analyses that I discussed in Chapters 4 and 5 demonstrated that the Ecology and Evolution of Infectious Disease (EEID) proposal was a clear example of a boundary object. These analyses also suggested disciplinary factors that acted as a source for negotiation topics and specific sites within the proposal that enabled this exchange to occur. However, these findings left gaps in understanding the negotiation process. Specifically, I needed to determine the exact disciplinary factors that were negotiated and how these negotiations occurred. In addition, I wanted to understand what constituted a successful negotiation and subsequently, a successful proposal. This query was particularly relevant because although the EEID team submitted a compliant proposal, the National Science Foundation (NSF) did not award funding. This outcome suggested that successful interdisciplinary collaboration and proposal development were not dependent on the winning of funds and vice versa. To address these issues, I examined a variety of negotiation examples using data derived from the coding analyses of emails, track-changes comments, and interviews, as well as examination of proposal text. As with previous analyses, the proprietary nature of the EEID proposal limited my ability to use direct quotes from the text. My findings are therefore primarily supported by participant input and proposal paraphrasing.

6.1 IDENTIFICATION OF NEGOTIATION FACTORS

I conducted coding analyses on the conversations held between EEID team collaborators

through both emails and track-changes comments recorded in all drafts of the EEID proposal's project description. These analyses revealed numerous negotiation factors ranging from figuring out meeting times to determining the primary goal of the research design. Of note, emails and the track-changes comment feature in Microsoft Word could both be considered boundary objects. However, I used these modes of discourse to identify negotiation factors that were resolved in the EEID proposal instead of how these alternate objects themselves framed negotiations. This clarification serves to further emphasize the complexity and need for additional research on boundary objects and their surrounding systems.

I performed the email analysis on and coded the text of a total of 111 emails that were written between October 6, 2014 and March 18, 2015. Eleven of the 13 EEID team members participated in one or more of the emails. The conversations that occurred through email were sequential and asynchronous. Email was used primarily to coordinate and manage the collaborative team. This mode of communication was also used to discuss components of proposal content and development at a high-level. The major codes and their occurrence that I determined from the emails are depicted in Table 9.

Table 9. *Primary codes and their occurrence in emails derived from coding analysis in total number of instances per code and % of total instances*

Codes	Total # of Instances	% of Total Instance
Administration	42	15.8%
Methods and approach	42	15.8%
Collaboration management	40	15.0%
Disciplinary knowledge	22	8.3%
Simple acknowledgement	16	6.0%
Response to reviewers	15	5.6%
Research need / significance	13	4.9%
Mechanics of execution - labor	12	4.5%
Institutional requirements	11	4.1%
Continuity of research design	10	3.8%
Budget	9	3.4%
Agency requirements / priorities	9	3.4%
Interdisciplinary team	7	2.6%
Competence	6	2.3%
Writing and language	5	1.9%
Unrelated to EEID effort	3	1.1%
Research goal	2	0.8%
Innovation	1	0.4%
Outcome	1	0.3%
Total Codes	266	

Table 9 illustrates the prevalence and variety of topics that formed the email content. Administration was a frequent and recurring theme, occurring 42 times throughout the 111 emails and making up 15.8% of all codes. This code was comprised of relaying contact information, conveyance of deadlines, and setting meeting times. Collaboration management was also common, occurring 40 times in the emails that I analyzed and making up 15% of all codes. This code described instances of delegating tasks, organizing collaborator efforts, and

informing teammates of progress. Finally, the code for the mechanics of execution represented discussions pertaining to the level of effort offered by each collaborator in the actual conduct of the research. These three codes represented points of negotiation between collaborators that were conducted to delineate the collaborative process and the practical execution of the work. Their high occurrence demonstrated the need for and importance of these discussions and suggested that email was an accepted venue for management activities.

Multiple codes that I derived from the email analysis aligned with previously discussed factors of disciplinary identity. Discussions pertaining to research methods and approach were the most prominent example, occurring 42 times in the 111 emails and making up 15.8% of all codes. This code was characterized by comments regarding the introduction of methods, suggested changes to the existing design, and problems that were perceived. The code concerning the contribution of disciplinary knowledge, occurring 22 times, was also notable. This code was comprised of statements regarding disciplinary literature, studies and specific knowledge. This data demonstrated that research methods and approach as well as disciplinary knowledge were primary negotiation factors and were frequently conducted via email.

An additional group of email analysis codes centered on rhetorical strategies in response to agency requirements. These codes included response to reviewers (5.6%), demonstrating research need and significance (4.9%), continuity of research design (3.8%), maintaining funding budget (3.4%), meeting agency priorities (3.4)%, and demonstrating competence (2.3%). All together, codes pertaining to discussions of rhetorical strategy comprised 57% of the code instances. These codes represented negotiation factors that directly impacted the rhetorical strategies of the EEID proposal. In addition, the high occurrence of these codes demonstrated the need for and significance of these negotiations.

These findings from the email analysis were in accordance with my interview coding, disciplinary identity, and informational plasticity discussions held in previous chapters. These data demonstrated that the prominent negotiation factors between collaborators were focused on the collaborative process, disciplinary identity, and rhetorical strategies. I further supported and broadened these findings by performing a coding analysis on the track-changes comments in all drafts of the EEID research plan.

I conducted the coding analysis on a total of 169 comments made across 23 drafts of the EEID proposal project description. This section of the proposal formed the bulk of the research plan and was developed as directed by the *National Science Foundation (NSF) Proposal and Award Policies and Procedures Guide: Part I Grant Proposal Guide (GPG)*. The guide instructed the proposers to “address what they want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful” in the project description (National Science Foundation, 2014b, pp. II-9).

I analyzed this section of the proposal due to its importance and delineation of the complete research design. The track-changes comments served as a record of conversations held between collaborators in the development of this proposal section and thus demonstrated factors of negotiation. The codes that I derived from the track-changes analysis are depicted in Table 10.

Table 10. *Primary codes and their occurrence derived from the analysis of track-changes comments in total number of instances per code and % of total instances*

Codes	Total # Instances	% of Total Instances
Disciplinary knowledge and citations	45	27.4%
Methodological approach	33	20.1%
Writing style	31	18.9%
Language and terminology	24	14.6%
Formatting	9	5.5%
Prior research and data	6	3.7%
Continuity in research design	5	3.0%
Research need and significance	3	1.8%
Budget	3	1.8%
Innovation	2	1.2%
Competence	2	1.2%
Mechanics of execution	1	0.6%
Total	163	

Table 10 demonstrates the multiple codes that represented the content of the track-changes comments. Similar to the email analysis, the codes of disciplinary knowledge and methodological approach were the most prevalent, making up 47.5% of all codes. Disciplinary knowledge occurred 45 times in the 169 comments, making up 27.4% of all codes. This code was comprised of specific reference to research data and citations. The methodological approach code occurred 33 times and made up 20.1% of the codes. The content of this code included the identification of gaps or inconsistencies in the existing methodologies, suggestion of new approaches, presented solutions to methodological challenges, and opinions on feasibility. These discussions tended to be very focused and definitive. All of the codes discussed above represented significant factors of negotiation that were both addressed in the track-changes

comments and in emails. However, the content of these codes was more specific in the track-changes text compared to email conversations. For instance, instead of stating general knowledge from the field in the emails, specific citations and data were provided in the comments. Additionally, instead of suggesting general approaches in the emails, collaborators identified specific gaps in methods and offered solutions in the comments. The difference between these two venues demonstrated the importance of conducting analyses on both sets of text as each revealed different types of negotiations.

The codes of writing style and language and terminology were prominent in the comment analysis as well, which differed from my examination of the emails. This was due to the more specific nature of the content in the track-changes comments and their association with editing drafts. The code for writing style occurred 31 times, making up 18.9% of all codes. This code was comprised of comments regarding sentence structure, clarification of wording, and paragraph flow. The code for language and terminology occurred 24 times in the 169 comments, making up 14.6% of all codes. This code was completely comprised of suggestions for word substitutions, many of which were due to inappropriate disciplinary use. The codes for writing style and language and terminology were highly specific and represented important factors of negotiation in developing the project description of the EEID proposal.

My coding analyses of email conversations and track-changes comments resulted in the identification of numerous factors that were discussed and negotiated between EEID collaborators. The most prominent of these factors were disciplinary knowledge, methodological approach, writing style and language, and collaboration management. These factors align with my previous findings discussed in Chapter 4. I demonstrated that differences in disciplinary identity existed in knowledge base, modes of thinking and research methods, writing style and

language, motivation to work and measures of success, and attitudes towards interdisciplinarity. These differences required negotiation and reconciliation in order to effectively create a cohesive proposal. My findings concerning satisfying informational requirements, as discussed in Chapter 5, also align with these findings. The identification of the research proposal's plastic elements with respect to rhetorical strategies alluded to sites in the proposal where negotiation of disciplinary identity and genre knowledge could occur. Thus, my findings suggest that the primary types of negotiations that occur through the EEID proposal boundary object involve differences in disciplinary identity, to include disciplinary knowledge, methodologies, and writing style and language. In addition, these disciplinary factors are negotiated at specific sites in the EEID proposal, through the plastic rhetorical strategies of research need, research means, and research cohesion. In the following section, I further discuss and demonstrate these types of negotiations and how they occur in the EEID proposal through the presentation of a variety of examples.

6.2 NEGOTIATIONS OF DISCIPLINARY IDENTITY TO BUILD RHETORICAL STRATEGIES

The prominent factors identified in the preceding section were negotiated with the overarching goal of creating a cohesive research plan that addressed the needs of the NSF EEID Program. More specifically however, particular negotiations of disciplinary identity were conducted in order to produce the action of developing cohesive and effective rhetorical strategies, all designed to maximize the proposal's appeal to the agency and reviewers in an attempt to win funding. Although this system was complex, Figure 2 demonstrates three of the prominent relationships between negotiation factors, rhetorical strategies, and the funding

agency.

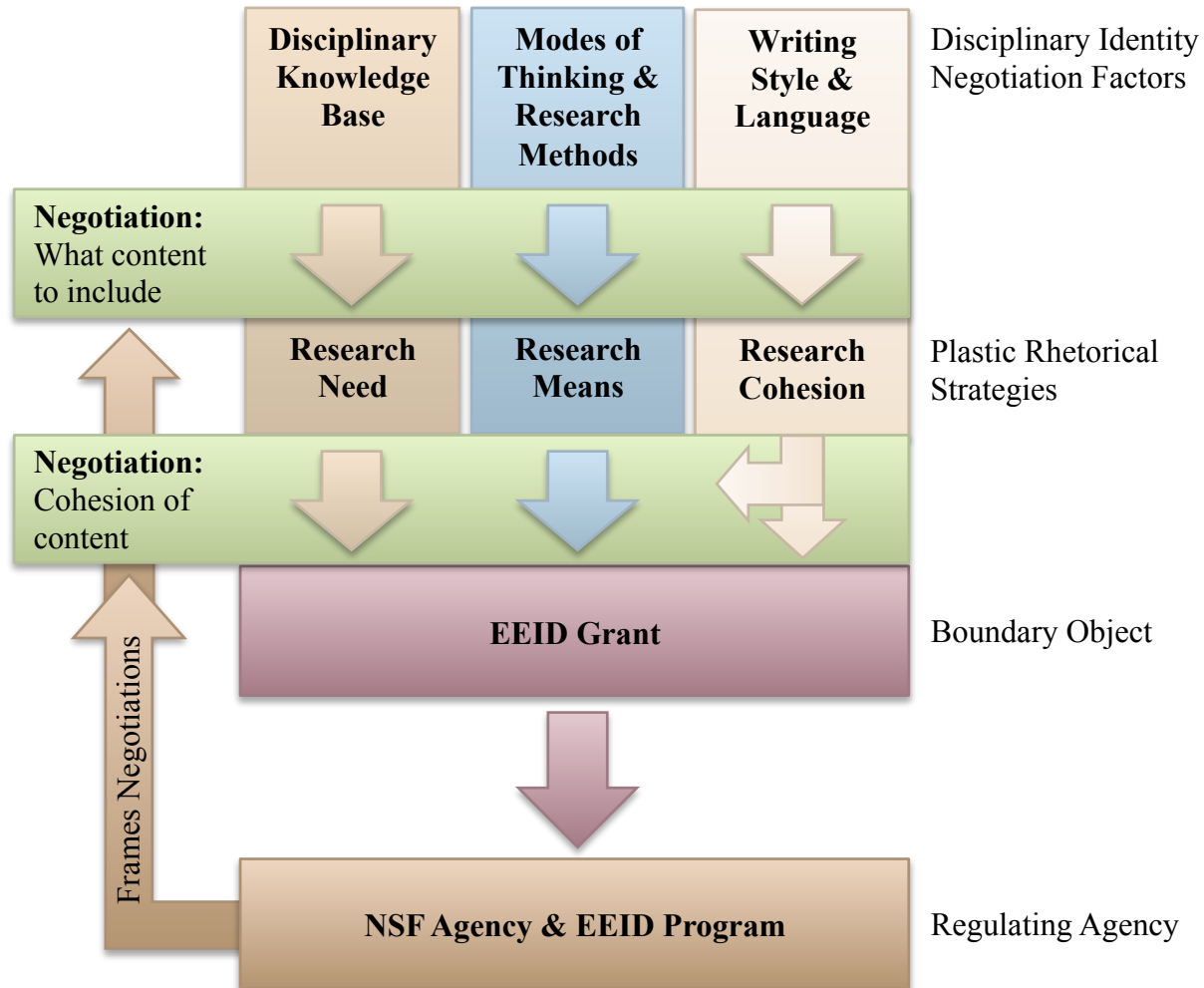


Figure 2: Relationships between negotiation factors, rhetorical strategies, and funding agency.

I examined three prominent negotiations that occurred in the development of the EEID proposal in detail. These negotiations centered on determining the content of three rhetorical strategies that would most appeal to the agency. The collaborators conducted the first negotiation involving the disciplinary knowledge base to establish a research need by defining a

territory for the work and gaps in existing knowledge. Since multiple disciplinary territories were involved, negotiation was required to identify, delineate and convey a unified need. The collaborators conducted the second negotiation of disciplinary modes of thinking and research methods to establish the research means, or the methods by which the research need would be met. Again, negotiation was required due to the inclusion of multiple disciplines and their varied approaches. This negotiation resulted in the identification, modification, and description of a cohesive set of methods that best addressed the primary goals of the study. Finally, the collaborators conducted the negotiation of disciplinary writing style and language in an effort to create one voice throughout the document. A unified writing style enhanced the proposal's readability and reviewer comprehension, and demonstrated research and team cohesion. These sets of negotiations were critical in the development of the EEID proposal and its ability to appeal to the NSF. In turn, the NSF and EEID Program framed these negotiations through the publication of their priorities, the request for proposals (RFP), the GPG, and reviewer comments. In the following sections, I examine the negotiations of disciplinary identity in detail.

6.2.1 Disciplinary knowledge base and research need. As an interdisciplinary effort, each collaborator brought different scientific knowledge to the EEID proposal. The negotiation of this disciplinary knowledge was therefore necessary to define a cohesive research need with a territory and gap in knowledge that was applicable to all disciplines involved and that appealed to agency needs. I conducted the following analysis to demonstrate this negotiation. My findings were supported by email and track-changes coding data, the 2013 and 2014 EEID proposals, corresponding reviewer comments, the RFP, and observations of the EEID Program website.

Agency framing. The EEID Program provided information and guidance on agency priorities through their website and the RFP. Two priority areas were heavily emphasized and included the topic of research and a need for interdisciplinarity. An overview of topic priorities was provided in a synopsis on the EEID Program website that stated, “the central theme of submitted projects must be quantitative or computational understanding of pathogen transmission dynamics. The intent is discovery of principles of infectious disease transmission and testing mathematical or computational models that elucidate infectious disease systems” (National Science Foundation, 2014a, p. n.p.). This text was also included and elaborated upon in the RFP which stated that “regardless of the system or approach taken, a proposal must have a significant focus on the ecology of disease transmission to be eligible for funding” (Scheiner et al., 2014, p. 5). The subject matter guidance given by the agency provided a framework for the researchers to use when defining the research need. The focus of the disciplinary knowledge and identified territory and gap had to involve infectious disease transmission.

The merit award information described in the RFP also provided the researchers with some insight into agency priorities regarding research need. The submitted proposals were reviewed according to specific criteria. For example, the studies were assessed for intellectual merit and significance. “The Intellectual Merit criterion encompasses the potential to advance knowledge... and understanding within its own field or across different fields” (Scheiner et al., 2014, p. 11). The study’s significance was determined by asking the following:

Does the project address an important problem or a critical barrier to progress in the field? If the aims of the project are achieved, how will scientific knowledge, technical capability, and/or clinical practice be improved? How will successful completion of the aims change the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field? (Scheiner et al., 2014, p. 11)

The EEID collaborators used this agency guidance on topic to examine their own research and

disciplinary knowledge in order to identify a research need that fit within agency priorities. The development of a research need was further guided by the additional agency priority of interdisciplinarity as stated within the RFP:

Research in EEID is expected to be an interdisciplinary effort that goes beyond the scope of typical studies funded by the standing programs of the partner agencies. They [the researchers] should bring together such areas as anthropology, bioinformatics, computational science, ecology, economics, epidemiology, evolution, food science, genomics, geography, global health, mathematics, medicine, microbiology, plant science, population biology, sociology, physical environmental sciences, systems science, and veterinary medicine... The history of the EEID Program has shown that the most competitive proposals are those that advance broad, conceptual knowledge that reaches beyond the specific system under study... Such proposals are typically interdisciplinary in their approach and/or the nature of the question(s) being addressed. (Scheiner et al., 2014, p. 4)

This EEID priority area of interdisciplinarity essentially forced the researchers to develop a research need that was applicable to the territories and gaps in knowledge across multiple disciplines.

Although still broad, the topic and interdisciplinary guidance offered by the EEID Program created a framework for the EEID collaborators. These individuals were required to identify a need that involved infectious disease transmission and that spanned multiple disciplines. More specific guidance was offered through reviewer comments on the team's 2013 submission.

Prior to the 2014 EEID proposal effort, the collaborative team submitted two proposals, one in 2012 and another in 2013. Neither submission was funded and both proposals received reviewer comments. The 2013 EEID team developed a research need and described it in the project description according to EEID Program guidance. The team accomplished this task through the identification of a territory and determination of a gap in knowledge. The territory involved transmission of infectious disease. Specifically, tick populations and the diseases they

carried were increasingly coming into contact with human populations through expansion of tick home ranges. This scenario increased risk to human health through elevated exposure to and infection by tick-borne disease, as well as potentially ineffective treatment due to misdiagnosis. The team identified the gap in knowledge as a lack of understanding of the actual risk that the tick species, and the specific pathogen it carried, presented to local populations due to this home range expansion. Therefore the EEID collaborators presented the following research need to the agency in their 2013 submission: interdisciplinary research into the ecology of a specific tick species and pathogen was necessary at expansion sites to determine actual risk to human populations in order to protect human health (2013 EEID Proposal, unpublished data, October 1, 2015).

The reviewers understood and appreciated the research need but expressed concerns regarding the established territory. Specifically, the reviewers commented on a lack of social science integration, which if included, would have provided insight into the human side of the equation. In addition, the reviewers noted a lack of consideration of additional factors that could impact home range expansion. The EEID collaborators were able to use this reviewer feedback in addition to the RFP, GPG, and program website to frame the re-design of their research need in the 2014 submission.

Negotiation of disciplinary knowledge base. The collaborators used the 2013 EEID proposal as a starting point for the negotiation of disciplinary knowledge base to develop the rhetorical strategy of research need in the EEID proposal. I collected records of the negotiations of disciplinary knowledge from email conversations, track-changes comments in the project description, and modifications to drafts. The first example of this negotiation focused on defining the research need. The data demonstrated that Anne, the Principal Investigator (PI) for

the effort, initiated discussions pertaining to defining the territory. She was concerned with the reviewer comment that the team did not adequately consider alternate reasons for home range expansion, and in turn, pathogen variability. Mark, a microbiologist, stressed potential causes stemming from population genetics, which were included in the 2013 submission. He justified his suggestion in an email conversation by describing his theory and applying it to potential tick invasion scenarios. In contrast, Matt, an ecologist, suggested a root cause in the relationship dynamics between mammal and tick populations. He presented his theory through email summaries and citations. Although these explanations were different and possibly led to competing hypotheses, both theories were emphasized in conversations and the latter was integrated into the existing EEID proposal. This consideration and incorporation of multiple disciplinary knowledge bases emphasized the interdisciplinarity of the proposed project.

The preceding negotiation was apparent when I compared the 2013 and 2014 EEID proposal submissions. Within the 2014 EEID proposal submission, the territory remained in alignment with the previous submission and program priorities by focusing on ticks, tick-borne diseases, risk to human health, and on the same tick species and pathogen. However, this territory was also refined to more clearly emphasize the observed variability in pathogen prevalence in multiple geographic locations. The gaps that were identified in knowledge were also refined and subsequently broadened compared to the preceding submission. The gaps focused on the lack of knowledge concerning the multiple root causes for the variability in pathogen prevalence with a focus on potential population genetics and ecological interactions involving hosts.

Additional instances of the negotiation of disciplinary knowledge concerned the use of supporting literature. The team had to decide on a selection of appropriate research that was

published and peer reviewed to include in the proposal. The EEID team used emails and track-changes comments to request, suggest, and negotiate which supporting literature to use in the project description. Numerous points in the text were identified as needing a supporting reference. Team members from ecology, microbiology, molecular biology, and mathematics offered suggestions at different points by citing specific studies. Most of the suggestions were accepted and included in the final submission. This outcome was likely due to the existing cohesion of the research team and their understanding of the proposed research territory. An inexperienced collaboration working on a new proposal may require more negotiation.

This negotiation was significant because the literature represented disciplinary knowledge and was used to help establish the proposed research territory. Specifically, a careful selection and presentation of studies demonstrated the team's knowledge of the relevant fields. The studies also created the foundation for the proposed research by demonstrating limitations and gaps in knowledge within these fields. Depending on the collaborating team and their project, this negotiation and selection can be challenging because the literature is pulled from different disciplinary sources, but has to be presented in a cohesive manner to address an interdisciplinary problem and audience.

By acting as a boundary object, the EEID proposal enabled the negotiation of disciplinary knowledge bases. Specifically, emphasis on the molecular biology and ecology knowledge bases resulted in a modified presentation of the research need compared to that presented in the 2013 submission. The 2014 version of the research need was more precise in its delineation, but more broad in its focus as the group aimed to identify physiological, genomic, and ecological factors that influenced pathogen prevalence. In addition, negotiation of what literature to include in the proposal resulted in the selection of a set of studies that defined a cohesive research territory. In

summary, the EEID collaborators productively negotiated different sets of disciplinary knowledge to create a research need in the proposal that better appealed to topic and interdisciplinary program priorities.

Outcomes of negotiation. The EEID team successfully negotiated disciplinary knowledge from 10 primary scientific disciplines to produce a concise and cohesive research need. The team's success in this endeavor was demonstrated by their compliance with the territory requirements presented in the RFP and EEID Program website. In addition, the team addressed the 2013 reviewer comments and broadened the study focus. Therefore, the EEID team's negotiation of disciplinary knowledge was successful.

The success of this negotiation was confirmed by two reviewers who each approved the research need and rated the proposal at "good/very good" and "excellent." A reviewer stated, "this proposal fits well into the goals and desired coverage and integration of an EEID project" (Reviewer 1, unpublished data, March 18, 2015). In contrast, two reviewers questioned the success of the negotiation as demonstrated by their comments and ratings of "good/fair" and "good." Reviewer 2 took issue with the research need and disagreed with the review of the 2013 submission:

The proposal by XXX et al addresses... variation in prevalence in tick populations... I'm not convinced the proposal has been improved by the broadening of focus, and it is not the case that the prior focus on disease ecology of an invasion front is too narrow; rather, addressing the effort requires a thorough consideration of the various other contributing factors, so that the effects of the expanding front can be isolated in the analyses. The proposal now aims to address so many aspects and challenges of basic biology... that the unifying ideas become lost. (Reviewer 2, unpublished data, March 18, 2015)

Reviewer 2 made the point that too broad of a focus could be problematic. Losing a central and unified focus could lead to an ineffective study as the data from each component would not align to address a common need.

Reviewer 4 agreed that the study aligned with agency priorities, but also critiqued the research need by asking, “it seems to fit very nicely within the project call, although perhaps [the] focus could still be broader and made potentially more generalizable to other diseases/disease systems in some way?” (Reviewer 4, unpublished data, March 18, 2014). The reviews of the 2014 submission were conflicting. Two individuals fully approved of the need, one preferred a narrowed focus, while the last reviewer wanted an even greater breadth of inquiry.

Similar inconsistency existed in the responses to the team’s interdisciplinarity. Although the 2013 reviewer comments approved the interdisciplinarity of the team, the 2014 reviewers offered criticism. Specifically, Reviewer 1 commented positively on the disciplinary coverage and integration. In contrast, Reviewer 4 stated that “[I am] not sure that the project is as interdisciplinary as claimed (there are a lot of biologists)” (Reviewer 4, unpublished data, March 18, 2014). This inconsistency was further demonstrated by a statement in the review summary:

A strength of this proposal is the project team assembled, with an excellent system and extensive experience working on the system... There is strength in the integration across the proposal of the different elements and the diverse project team, although heavily biology focused. (Review Summary, unpublished data, March 18, 2014)

The mention of a “diverse project team” directly contrasted with “heavily biology focused.” These results suggested a distinct lack of a commonly adhered to or understood definition for interdisciplinarity, particularly across scientific disciplines. This issue posed a significant problem seeing as though interdisciplinarity was a key agency priority.

These reviewer comments demonstrated that the EEID team succeeded in designing and conveying a research need that aligned with agency priorities. This success suggested that the agency provided adequate information to frame the general territory of disciplinary knowledge. In addition, the reviewers adhered to the merit review criteria concerning general territory while

critiquing the proposal. However, the lack of consistency in the critiques in response to the breadth or focus of territory and interdisciplinarity demonstrated a potential disconnect between the EEID team and the reviewers. This situation was problematic for the EEID collaborators because even when they used all information at their disposal, they still could not predict the research need or level of interdisciplinarity that would align with each reviewer's preference. This scenario is likely the result of two issues. First, the NSF may be providing too little guidance concerning the expected breadth of territory and level of interdisciplinarity to the researchers and the reviewers. In addition, the reviewers may not be adhering to the NSF guidelines and are introducing a high level of subjectivity into the review process. Either way, this disconnect contributed to the ruling to not fund the 2014 EEID submission. This outcome demonstrates that a team can successfully produce a compliant proposal, but due to factors outside of their control, the proposal may not have a successful funding outcome.

6.2.2 Mode of thinking, research methods and research means. The interview data previously demonstrated that the modes of thinking and research methods were distinctly different between the scientific disciplines involved in EEID proposal development. Therefore, the negotiation of this disciplinary identity factor was required in order to develop a cohesive research goal and methodological approach, and to demonstrate an effective research means that appealed to agency needs. To illustrate this finding, I used data gathered from email and track-changes coding analyses, the 2013 and 2014 EEID proposals, as well as observations of team meetings, the EEID Program RFP, and the 2013 and 2014 EEID submission reviewer comments.

Agency framing. The EEID Program offered guidance concerning the types of methods that were acceptable in addressing the need to research systems of infectious disease

transmission. The requirement for an interdisciplinary approach, as stressed in the RFP, mandated the inclusion of multiple disciplinary methods in the design:

Important new insights into the drivers and control of infectious diseases in humans and other species can only be achieved by integrated approaches that take into account the ways in which the natural and social environments affect the emergence and spread of infectious disease. (Scheiner et al., 2014, p. 4)

The RFP suggested that the only way to address program priorities was through the integration of multiple disciplinary approaches. This sentiment was further emphasized through the listing of acceptable approaches and a required modeling component as follows:

Diverse modeling approaches are appropriate, including, but not limited to, mathematical equations, computational simulations, geospatial algorithms, and statistical models... Models should aim to be explanatory beyond the specific system under study and must be well-characterized and rigorously tested. Proposals must describe how models will be developed, evaluated, and disseminated... Likewise, strategies for data collection must be well designed to contribute to and test model design. (Scheiner et al., 2014, p. 5)

Additionally, the RFP stated,

Depending on the hypotheses or research questions being addressed, investigations might entail some combination of laboratory experiments, field observations or manipulations, public health interventions (although clinical trials are beyond the scope of the EEID Program), analysis of social and cultural processes, or ethnographic studies. Research may also focus on novel analyses of existing data and/or theoretical investigations of ecological and evolutionary dynamics. (Scheiner et al., 2014, p. 5)

Although still broad, the RFP offered a variety of examples of acceptable methods with the only requirement involving a modeling component. Thus, the EEID team understood that multiple disciplinary methods were necessary, and these methods had to complement each other in order to effectively inform a single mathematical model. This information was critical in developing a research means that would appeal to EEID Program priorities.

The merit review criteria, also presented in the RFP, offered additional insight into agency priorities particularly with respect to the innovation and reasonableness of the designed approach. The review criteria for innovation were detailed through the following questions:

Does the application challenge and seek to shift current research or clinical practice paradigms by utilizing novel theoretical concepts, approaches or methodologies, instrumentation, or interventions? Are the concepts, approaches or methodologies, instrumentation, or interventions novel to one field of research or novel in a broad sense? Is a refinement, improvement, or new application of theoretical concepts, approaches or methodologies, instrumentation, or interventions proposed? (Scheiner et al., 2014, p. 11)

Novelty of the approach was important to consider due to the understanding that innovation leads to greater discovery. However, the mechanics of the approach were likely more important than novelty, as the researchers were required to propose a research means that would be feasible and successful. The approach review criteria were conveyed through this series of questions in the RFP:

Are the overall strategy, methodology, and analyses well-reasoned and appropriate to accomplish the specific aims of the project? Are potential problems, alternative strategies, and benchmarks for success presented? If the project is in the early stages of development, will the strategy establish feasibility and will particularly risky aspects be managed? (Scheiner et al., 2014, p. 11)

The preceding priority synopsis and merit review criteria provided a broad framework for the researchers, which emphasized the integration of interdisciplinary data sources to inform a predictive model. This priority information was augmented by budget restrictions. The EEID team was required to design a research means that did not exceed \$2.5M over a period of five years. Therefore, the team had to consider the labor, materials, travel, indirect costs and other expenses that were associated with the execution of the research design. The EEID team used this framing information in addition to their 2013 EEID submission and associated reviewer comments as a starting point for methods negotiations.

Even though the RFP guidance was useful, the information provided through the 2013 reviewer comments was invaluable in identifying the weaknesses of the proposed methodology. The reviewers were pleased with the interdisciplinarity of the effort but revealed issues with the research means. The reviewers identified a series of gaps in some of the approaches. The

reviewers suggested that the researcher's choice of one approach in particular might lead to misleading results, and comparison of these results between different geographical locations was problematic. This indicated a lack of cohesion between methodological approaches that informed the mathematical model. In addition, the reviewers were concerned that a lack of social science protocols would result in the absence of important data concerning human populations impacting the infectious disease system.

The reviewer comments and the RFP guidance provided a fairly developed framework that enabled the EEID team to identify areas of the research means that needed to be changed and what these changes should look like. Thus, the agency framing set the stage for the EEID team negotiations that integrated disciplinary modes of thinking and research methods to develop the research means.

Negotiation of modes of thinking and research methods. The majority of negotiations that occurred during the development of the EEID proposal were focused on delineating the research means. The EEID team addressed the agency requirement for interdisciplinarity by using four disciplinary methodological approaches, stemming from microbiology, molecular biology, ecology, and mathematics. All of these methods were carefully chosen to address the common research goal. Three methodological approaches were designed to determine the impact of specific biological and environmental factors on the variability of pathogen prevalence. The data from these independent methods each provided insight into a piece of the disease system and were then combined to inform the mathematical model. In turn, this model then represented the entire system, and could be used to predict disease risk. Anne stated in her interview,

I think one smart thing about the EEID process is that its supplemental core is a mathematical model, and to me, the goal about models is that it allows you to pull data

together form a variety of expertise and techniques. I think by linking all of the different pieces back to the mathematical modeling concept, it helps you really pull the ideas together well. What's going on and how does this system work, because the real world has all of these pieces to it, and so I think the model is the closest way to actually doing the entire system while still breaking it apart and understanding the pieces. (Anne, interview, October 15, 2014)

Creating a cohesive methodological approach that informed the model was the underlying framework and reason for the negotiation of research means.

Specifically, the negotiation of research means resulted in four protocols. The first set of protocols in the EEID proposal stemmed from microbiology and involved transmission studies to track infection and transmission rates in tick populations. These protocols sought to determine how the pathogen was most effectively transmitted within a tick population. In turn, this data would inform the mathematical model by providing information on pathogen spread and transmission rate within ticks. The second set of protocols was derived from molecular biology and involved population genetics. These data provided insight into why there was an increased pathogen prevalence in some geographic areas vice others due to tick demographics. These data would provide the mathematical model with the factors associated with the tick populations that impact prevalence. The ecological field studies were designed to determine additional climactic and habitat factors that impacted pathogen prevalence. Again, these data further informed the mathematical model.

The model was then designed to combine the transmission, population genetics, and field data to represent a larger ecological system. The model demonstrated how each factor, from tick physiology, to host species presence, to climate, and any combination thereof, could change the prevalence of the infectious disease in a geographic area. This research means contributed to a better understanding of the identified infectious disease system as a whole.

Multiple negotiations occurred before the research design described above was finalized.

The first example of this negotiation involved the inclusion of social science protocols in the research design. As mentioned, the reviewers of the 2013 submission criticized the lack of social science protocols that would shed light on human factor contributions to infectious disease transmission. The EEID team considered this criticism and worked to develop a research design to write into the EEID proposal that would appeal to this agency priority. Jen, an ecologist, raised the issue of the lack of social science protocols and offered the initial suggestion on how to address this deficiency. This email was followed up with a meeting between Anne and Jen. Initially, both collaborators agreed for the need of the new social science based protocol. Jen suggested an interview protocol that would reveal human perception of tick-borne disease. Anne countered by asking how the findings from this interview would fit into the overarching research question. Jen then suggested that a survey might be easier to design and would collect more applicable information. Anne agreed, and having previous experience in survey design, she further questioned Jen on how the survey could be used to effectively compare the perceptions of two different human populations from the geographical regions involved in the study. Anne was also concerned with how the survey data would complement the other protocols and inform the mathematical model. Both Anne and Jen considered the survey design and ultimately agreed that the expertise of an additional collaborator would be necessary to appropriately develop a survey that would gather relevant information.

The back-and-forth exchange between Anne and Jen enabled the identification of issues with the proposed social protocols. Each collaborator had a different mode of thinking. Anne's mode of thinking stemmed from mathematics and biology, and had a systems focus. Anne was primarily concerned with determining what the factors were that caused variability in pathogen prevalence and how she could pull these factors together to describe a system. Therefore, the

social protocol had to collect pertinent data that directly contributed to the primary goal of the study and, more specifically, the mathematical model. This mode of thinking also made the demonstration of methods continuity and a unified research means a high priority for Anne. In contrast, Jen represented a different mode of thinking common among ecologists. She was concerned with teasing apart the system and understanding relationships and causality. Jen wanted to know why we cared about variability in the pathogen prevalence, and therefore was concerned with the more human side of the equation. This added an additional relationship into the proposal which she hoped, would enhance the significance of the research and better align with agency priorities.

Following email exchanges and this meeting, the team decided against adding a social protocol to the EEID proposal. Anne noted in a later meeting that the exclusion of the human aspect made the proposal more reasonable and tighter as a project. In this case, the EEID proposal was the center of this negotiation. The need to change the research design to include human factors spurred the exchange between Anne and Jen. Anne's priorities of a system focus and designing a cohesive set of methods that informed the mathematical model overshadowed Jen's desire to broaden the research design and add significance by aligning the methods to an additional agency priority. This situation served as an example of two individuals negotiating their differing modes of thinking and research methods in order to develop the rhetorical strategy of research means in the EEID proposal. In addition, these two collaborators had differing priorities in the design of the research means, demonstrating methods continuity versus significance. This difference in priority and subsequent negotiation concluded in the lack of a compromise and the exclusion of the proposed social protocol. Even though this outcome occurred, the negotiation still addressed important issues, forced the team members to balance

content and priorities, and the proposal was still successfully submitted.

The need for cohesion of the research means drove additional negotiations between different disciplines, as demonstrated by the following example. The microbiologists and molecular biologists in the EEID team developed an assay protocol that produced data on the transmission of pathogens within a tick population across two sites. Matt, an ecologist and highly involved collaborator on the team, suggested a change to this assay protocol both via email and comments in the project description drafts. Specifically, he stated,

One thing I want to get some feedback on is the idea to do XXX analysis of the field collected ticks. This seems like a natural extension of the lab work and I would like to formally include it in the field section if costs allow. (Matt, unpublished data, November 17, 2014)

Adashe, a pathologist, expanded upon Matt's suggestion:

On the issue of XXX analysis, I am also of the idea that this be on field collected ticks. I am thinking of maybe comparing between two areas, one with high infection rates versus one with low infection rates. I was also thinking that maybe we could do the same analysis over time, comparing the XXX over different seasons, based on the assumption that tick infection rates will be different by seasons. Thoughts? (Adashe, unpublished data, November 18, 2014)

These two collaborators were attempting to enhance cohesion across the disciplinary methods by incorporating the analysis of field collected ticks across additional sites and at different times of the year into the microbiology protocols. This would result in the field protocols more closely aligning with those from microbiology. Specifically, this would strengthen the justification for using multiple study sites, which was a common theme throughout the proposal. Second, the data would support the climate and environmental findings from the field work. Finally, the resulting data would be more representative of the studied field locations and therefore, in theory, better inform the mathematical model. However, this suggestion to use field collected ticks across multiple sites and times was done without a full understanding of the intricacies of

the disciplinary method.

The sole microbiologist on the team, Craig, clarified some of the challenges associated with this methodological suggestion by adding a comment to the project description draft:

I agree it would be useful, very interesting and informative to be able to test field collected ticks from the different sites, but I think that would be a study by itself. [We] would need background data on XXX in the different areas, different hosts would affect the XXX, [and] we are dealing with different species of tick. [I] wonder how many confounding effects we would be looking at. As it stands, this was written expecting the XXX to be tested and for their XXX to be field collected.... [I] think we need to get a handle on some of the basics before such a large scale approach to XXX works. Information on whether the presence or absence of particular XXX affects transmission; [I] think we need to start with one system and see what we get – then look for similar patterns in the other and over multiple years, etc. (Craig, unpublished data, November 18, 2014)

Craig added his expertise in microbiology and research design to illustrate the complexities involved in performing the analysis across different sites. Without this disciplinary insight, Matt and Adashe would have proposed a methodology that was too large in scope for the current study. In turn, the data produced by this protocol would not have been as effective in informing the mathematical model. This negotiation of research means resulted in maintaining the original protocol and not explicitly comparing populations across additional sites and seasons.

Outcomes of negotiation. The EEID team successfully negotiated different disciplinary methods to create the four protocols detailed above. Interestingly, the three disciplinary methods essentially acted as independent but complementary studies. The fourth disciplinary methodology, the mathematical model, integrated the data from the other three protocols to create a cohesive research means to address the research need. The majority of reviewers were pleased with this cohesion and one stated,

The PIs detail a collection of well integrated studies that will ultimately be used to inform mathematical models. Laboratory--based empirical determination of transmission rates will be fed into the mathematical models, and it appears that the PIs have detailed a series of field and laboratory studies that are nicely integrated. (Reviewer 1, unpublished data,

March 18, 2015)

The only criticism in this regard stemmed from Reviewer 2 who did not critique the integration. Instead, this individual feared that the collaboration was taking on too many components of the system and the broadened focus was not beneficial (Reviewer 2, unpublished data, March 18, 2015). These reviewer comments indicated that the EEID team successfully negotiated and designed a research plan where each protocol complemented the other and effectively informed the mathematical model.

Also of interest, none of the reviewers critiqued the lack of social protocols, even though this was a primary concern with the preceding submission. This outcome may have been due to two factors. First, it was possible that the human elements were not a priority for these particular reviewers. If this scenario was true, it again emphasized a lack of consistency in the review process. The second possibility was the reviewers felt that the study presented, and its newly broadened focus, was comprehensive enough. Either way, this outcome further demonstrated the subjectivity and unpredictability of the review process.

The microbiology protocol that resulted from the negotiation discussed above received conflicting reviews. Two reviewers did not critique the protocol whereas Reviewer 1 approved by stating that “the transmission and population genetics studies are well designed and well described” (Reviewer 1, unpublished data, March 18, 2015). In contrast, Reviewer 2 was highly critical and pointed out multiple gaps in the method, summarizing his or her thoughts as follows:

The ecological mechanisms addressed in the XXX assay are also not clearly laid out nor are the implications of possible outcomes well considered. There is the assumption that XXX affect the pathogen prevalence based only on correlation data (where it seems experimentation is feasible), which is flawed. (Review 2, unpublished data, March 18, 2015)

Even though only one reviewer expressed concern for this methodology, this critique was

emphasized in the review summary and presented as a primary concern. This outcome begs the question of why are negative critiques consistently highlighted even when offered by a minority of reviewers? Also, why did this reviewer's opinion trump those of the other three? Was he/she the sole expert in this method on the panel? In response to the first question, negative critique offers suggestion for improvement whereas a simple "good job" will not induce change. However, if three of the four reviewers thought the protocol was fine, did it need improvement?

As with most of the discussions thus far, this review scenario demonstrated more inconsistency in the review process with respect to reviewer subjectivity and whose review should take priority and why. Again, the successful negotiation of research means to create a compliant proposal does not necessarily translate into a successful funding outcome. This scenario suggests that a critical examination of the review process for potential sources of inconsistency and subjectivity must occur.

6.2.3 Writing style, language, and research cohesion. The development of complementary protocols was not the only way to demonstrate cohesion of the research means. The use of a consistent writing style and carefully chosen language was necessary to bring each discipline together and demonstrate that each independent idea spoke to the other to create a cohesive research means. Therefore, the negotiation of writing style and language, components of genre knowledge, was a necessary process in the development of the EEID proposal. Anne pointed out the importance of achieving "one voice" throughout the proposal during her interview:

People write very differently and you need to have it sound like it's one narrative... [by] changing the tone and tenor of the people's writing without losing your content.... [Craig] and I have a pretty good understanding of whether or not to craft together, now that I can anticipate what he is going to write. He is not always the best about writing a section on

how I would derive the parameters out of his experiments for a mathematical model, and I still don't do well at writing exactly how he would nuance the PCR in keeping the same process. Although I can spell PCR now, which is far better than I used to be... so much of it just ends up being the readability because I have read those rants on grant reviews that the mathematician wrote this section and biology wrote this section, and they never actually spoke to each other. So definitely a lot of it is, did you really mean this, did you really mean that? So, that just takes a lot of practice or time spent in a room locked together. (Anne, interview, October 15, 2014)

Anne raised a very important point in that each component of the research design, in reality, did complement each other and informed the mathematical model. However, if the methods were not demonstrated clearly through the writing style and language, then the reviewer's understanding of this research cohesion would be lost. Therefore, it was extremely important to achieve one voice across disciplines, each of which had very different styles and terminology.

Anne emphasized the difficulties associated with this type of negotiation:

I surely think vocabulary is always a challenge. You have to sound intelligent when you write these [proposals], you have to use cutting edge language in each field. However, the likelihood that if you write sections on the development of sequencing, if you use the current language, not everyone else will understand that language, so that becomes a challenge. Well, how do I weave all of these things together and encourage [Simon] to write about it in his math section if it is a language he can't even understand because of his background? That gets to be a real challenge of meshing the fields. I mean, you say vector and I think vector borne disease, you say vector and you think direction and velocity. (Anne, interview, October 15, 2014)

The negotiation of what writing style and language to use was difficult. The collaborators had to maintain the appropriate disciplinary meaning they intended to convey but also alter that specific style and language so a multi-disciplinary audience would understand the intended meaning.

Anne, in addition to a selection of other collaborators, was integral in accomplishing this challenging task.

Agency framing. The NSF provided a structural framework for the writing of the EEID proposal. Specifically, the GPG provided detailed guidance on the format of the document, including specified page limits, margin and font sizes, and line spacing. The GPG pointed out

that these requirements improved readability and leveled the playing field between competing proposals. To supplement these basic requirements, the GPG also provided instruction on how to organize the proposal into content driven sections that included the cover page, project summary, project description, and others. The suggested content of each of these sections was elaborated upon (National Science Foundation, 2014b).

Although this guidance was useful in determining the overall structure of the proposal, little to no direction was offered with respect to expectations for interdisciplinary writing. The RFP requested a single proposal that was developed from an interdisciplinary team. This minimal guidance left decisions on writing style and choices of disciplinary language up to the collaborators.

The reviewers also offered little feedback with respect to interdisciplinary style and language. Review of the 2013 submission revealed the need for increased continuity and clarity through the identification of gaps both within and between disciplinary protocols. It took experience for Anne to know that these gaps were, in part, due to a lack of clear and cohesive writing that explicitly drew all of the protocols together under a central theme.

Negotiation of writing style and language. The project description section of the EEID proposal laid out the four disciplinary protocols proposed by the team. Similar to their 2013 submission, the collaborators chose to organize the research design discussion by breaking it into four distinct sections, each discussing a separate disciplinary protocol. This strategy emphasized the interdisciplinarity of the work and allowed for some separation of style and terminology. However, the entire proposal still had to flow and be understood by a varied audience. As such, the majority of negotiations that occurred over writing style and language centered around the clarification of ideas, making phrases more definitive, and using appropriate terminology to

convey the desired meaning. Since each discipline differed in both their writing style and terminology, this led to numerous negotiations. The following section illustrates a few examples.

As the lead on proposal efforts, Anne took the responsibility of unifying the writing styles and language across the document. However, collaborators assisted her as they understood the challenge she faced. Jim stated in an email that “I am happy to look over any drafts to offer further feedback. I can see where, stylistically, it is a challenge to merge the different sections when each is authored by a different person” (Jim, email data, October 20, 2014).

The first set of negotiations that I observed centered on clarifying definitions and choosing appropriate terms to convey the intended meaning. Jim, one of the ecologists in the group, repeatedly pointed out instances where terms were misused. Specifically, Jim stated in the track-changes comments of the project description that “ecology is being used in a colloquial sense here. Is there any specific ecological phenomenon that is being addressed here? If not, maybe an alternative (and less loaded) term could be used” (Jim, comment data, November 18, 2014). Even though Jim brought this to the attention of the team, the use of “ecology” in the sentence examined was not changed. Jim used more force when he pointed out the misuse of an additional term in a subsequent draft. He stated, “you are misusing the ecological term ‘edge effect.’ This should not be attributed to ranges. It is used for habitat at small scales. Ecologists will not like this misuse. Use range-boundary effect instead” (Jim, comment data, November 19, 2014). In this case, Jim expressed his disciplinary knowledge to the team. The team accepted this suggestion and the correct disciplinary term was used in the proposal.

Jim also pointed out instances where he did not understand terms and concepts, and as

such, he requested increased clarification. These comments were significant as Jim represented a potential reviewer who could have been from an unrelated discipline. These instances of needed clarification pointed to potential areas of confusion for the reviewers. Specifically, Jim identified terms such as “marker type,” phrases such as “higher genomic coverage than 454,” and modeling concepts stating that they were “way too vague... needs more explanation” (Jim, comment data, November 18, 2014). Interestingly, most of these suggestions were not accepted by Anne and the other members of the team. Some of these instances were deleted altogether, but the majority remained unchanged in the final submission. Potential explanations for this lack of change were that each discipline understood their respective sections and did not see the need for clarification. Or, the authors did not see clarification as high enough of a priority to sacrifice other text due to stringent page limitations. Time may also have been a limiting factor that prevented the ability to consider changing or clarifying terms. Either way, the collaborators had to negotiate the level of disciplinary cohesion that would ultimately be conveyed in the final submission. This team favored the maintenance of discipline specific sections in the methods descriptions, which contained specialized terminology and concepts. This may have been done out of necessity or preference to keep disciplinary identity and meaning intact.

The second set of negotiations concerning writing style and language focused on being more precise and definitive. From my experience as a professional proposal writer, increased precision helps convey confidence in one’s research design. This confidence gives the reviewers the sense that the researcher knows that his or her design will be successful and make great contributions to science, thus making this research well worth the federal investment. The EEID team made numerous suggestions in the track-changes comments to this effect. Common examples included switching the term “could” with “can,” “need to” with “will,” and “explore”

with “examine” or “assess.” Specific team members favored specific sets of terms. Jen (ecologist) and Adashe (pathologist) consistently suggested the terms “could” and “explore” in the track-changes comments. In contrast, Jim (ecologist) and Mike (molecular biologist) referred to these terms as “vague” and suggested the terms of “can” and “examine” as more definitive replacements. Both Anne (mathematics/biology) and Matt (ecologist) fell in the middle, suggesting the use of both sets of terms.

To illustrate this negotiation, the term “could” was replaced with “can” in this sentence: “alternatively, mice *could* be infected with the seed culture of XXX” (EEID Proposal Draft, unpublished data, November 19, 2014) compared to “alternatively, mice *can* be infected with the seed culture of XXX” (EEID Proposal, unpublished data, November 19, 2014). The term “could” indicated the possibility of executing a protocol whereas “can” conveyed the fact that the team was able to accomplish the task. Although subtle, the insertion of “can” conveyed an increased confidence in the design.

Similarly, terms were altered in the sentence, “to address these potential mechanisms, we *need to explore* two XXX-tick ecosystems” (EEID Proposal Draft, unpublished data, November 18, 2014). The term “need to” indicated potential tasks the researchers considered doing. Additionally, the term “explore” indicated that the researchers did not know what answers they were going to find. Mike changed the terms “need to” to “will” in order to convey the exact tasks the authors planned to conduct. In addition, Anne inserted “assess” to suggest a less open-ended analysis. This editing resulted in the sentence, “to do this, we *will assess* comparable systems in multiple regions” (EEID Proposal, unpublished data, November 19, 2014). This choice of terms made the statement more concise and definitive, and thus demonstrated confidence in an executable research design.

Increased expression of this confidence through more definitive statements was a common critique from both Mike and Jim. However, Anne maintained and added some of the less definitive terms throughout all sections of the proposal. The authors had to negotiate the level of confidence and precision they wanted to portray, as there was a delicate balance between confidence and cockiness. Being too self-assured of one's research might have soured the reviewers' opinion of the study or suggested that over-confidence in the design and outcomes could lead to flawed execution. In addition, Mark (microbiologist) suggested that the team should write the methods in a way to "create useful ambiguity" (Mark, meeting observation, November 6, 2014). Sometimes, less precision was useful and gave the reviewers the opportunity to come to their own conclusions regarding the design. Ultimately, Anne decided upon a mixture of terms that balanced the sense of confidence in the team's research design with humbleness in their ability to predict the outcomes, all in an effort to appeal to the reviewers. In addition, this balance was achieved through all sections of the proposal, to provide reviewers with a sense of continuity and cohesion between disciplinary contributions.

Outcomes of negotiation. The team succeeded in using writing style and language to create a cohesive proposal as demonstrated by reviewer comments, and a lack of criticism with regards to the writing. Reviewer 1 was the only individual who commented on the writing and he or she stated that "this project is well written and the PIs have made a strong commitment toward improvement from previous submissions" (Reviewer 1, unpublished data, March 18, 2015). This review suggested that the EEID team melded writing styles and chose appropriate language to demonstrate a balance between the separation and cohesion of the involved disciplines.

6.3 CONCLUSIONS

The preceding analyses demonstrated the types of negotiations that the EEID team performed and how they were executed in order to create a cohesive interdisciplinary research proposal. This team successfully negotiated disciplinary differences to delineate a clear research need, means, and cohesion in the EEID proposal. They did this through conversations held in face to face meetings, in email, and through track-changes comments in proposal drafts. In general, the resulting proposal appealed to the NSF reviewers and received numerous accolades.

These analyses also revealed a variety of interesting findings. The first finding involved the team's research means and the type of interdisciplinary methodological approach they created. In this case, three independent but complementary disciplinary approaches each answered an aspect of the research need. These disciplinary methods were then integrated to inform a single model that represented the entire system. The negotiation of this research means resulted in embracing and preserving each discipline and its unique qualities as well as combining all disciplines to broaden and optimize the ultimate findings.

The second finding revealed a significant disconnect between the researchers and agency reviewers with respect to expectations for proposal content. Despite the successful negotiation of disciplinary differences and submission of a compliant proposal, the NSF did not award funding. This outcome was due, in part, to an unpredictable and inconsistent review process. The reviewers of both the 2013 and 2014 submissions demonstrated a varied understanding of, adherence to, and prioritization of agency priorities and definitions of interdisciplinarity. This reviewer subjectivity and minimal reliability of the review process created a challenging scenario for the EEID team. The team was unable to predict agency needs with confidence, to effectively structure their rhetorical strategies, and to anticipate how well their proposal would be received.

This uncertainty may have resulted from one or more potential causes. First, the funding agency may not be providing adequate guidance to researchers and reviewers with respect to agency priorities and merit criteria. Second, reviewers appear to be subjective in the conduct of their critiques and do not strictly adhere to the guidelines established by the agency. Finally, the emphasis placed on negative reviews appears to be unbalanced with those of positive reviews. All of these potential causes result in low reliability of the merit review process. The findings from my study demonstrate the need for a critical examination of the review process and the identification of tangible improvements.

The previous boundary object analysis of the EEID proposal produced a variety of interesting conclusions ranging from the identification of key traits of disciplinary identity to the need for improved merit review. The significant findings from my research are further elaborated upon in Chapter 7.

CHAPTER 7

CONCLUSIONS

Team science, in the form of interdisciplinary and collaborative research, is a rapidly increasing trend (Cooke & Hilton, 2015). Although popular, this form of research is challenging and often arduous due to its complexity. Daniel Stokols et al. (2008) emphasize that “it is becoming increasingly clear that investments in team science are not uniformly cost effective, although they can be enormously valuable under the right circumstances” (p. S96). If this is the case, how do we achieve the right circumstances to improve the efficacy of scientific collaborations and the funding system? My study begins to answer this question, augmenting research from a variety of other fields.

The process of developing an interdisciplinary and collaborative research proposal is exceedingly complex. My study teases apart aspects of this process and offers insight into the differing characteristics between scientific disciplines. My findings also demonstrate how these differences are negotiated to create a cohesive proposal. Understanding these disciplinary characteristics can impact the development of a team and the execution of the collaborative process. My study also offers insight into certain challenges associated with the agency solicitation and review processes. Identification of these issues is the first step in finding ways to improve the funding system. In the following chapter, I discuss how my findings impact the collaborative process, the funding system, and potentially inform additional fields of research.

7.1 REALIZING THE DIFFERENCES BETWEEN SCIENTIFIC DISCIPLINES

Earlier in this dissertation, I discussed the common and false assumption that most

scientific disciplines share a high degree of similarity. This assumption perpetuates the belief that collaboration between these disciplines should be relatively straightforward because differences are minimal and disciplinary conflicts are easily resolved (Evans & Marvin, 2006; Lowe & Phillipson, 2009). A lack of awareness of these differences can be problematic by hindering the optimal development of a team and the collaborative process.

Ideally, the members of a collaborative team are carefully chosen for the unique, yet complementary expertise that they can offer to a scientific issue. If disciplinary character is not understood, a team cannot optimize its composition. In other words, an understanding of disciplinary characteristics and how they differ enables the identification of gaps in knowledge and abilities. This assists in determining the optimal combination of expertise to comprehensively, but not redundantly, address a research need (Cooke & Hilton, 2015).

In addition to team composition, unrealized differences between disciplines can hinder the collaborative process by preventing negotiation. This issue can result in increased work, confusion, and failure rates (Morse et al., 2007; Vogel et al., 2014). Stokols et al. (2008) expand upon this issue:

Conflict and tensions among members of a... team stemming from divergent disciplinary world views, competing theoretical and methodologic perspectives, different departmental affiliations, and dissimilar interpersonal styles hinder the formulation of clear goals and their accomplishment. While disagreements and conflict can contribute to knowledge construction, learning, and innovation, it is important to negotiate these differences as they can foster interpersonal tensions, social fragmentation and subgrouping, and non-overlapping (even competing) agendas; eventually they can undermine the collaboration's ability to meet its goals. Overcoming such conflicts requires that members of a collaboration establish familiarity with each other's way of thinking.... Members must be aware of the collaborative constraints, disagreements, and conflicts that they are likely to encounter over the course of the project and be prepared to dedicate considerable time and effort toward establishing common ground both intellectually and socially. (p. S105)

The results from my study inform these issues by offering a tangible method to increase

disciplinary awareness. My analysis, as discussed in Chapter 4, identified five prominent characteristics that significantly differed between the disciplines involved in the Ecology and Evolution of Infectious Disease (EEID) collaboration. To review, these characteristics included the disciplinary knowledge base, modes of thinking and research approach, writing styles and language, motivation to work and measures of success, and attitudes towards interdisciplinarity. The differences in these disciplinary characteristics between collaborators were a significant source for negotiation and therefore impacted the collaborative process. This study specifically demonstrated that the team members had to dedicate significant time and effort to arrange meetings, interact, negotiate and resolve differences with respect to knowledge base, research methods, and writing style.

The five factors identified above can be used to gain a greater understanding of disciplinary character. The resulting profiles can inform team development. First, the identification and understanding of these five characteristics can be used to critically assess a research need. This method answers Cooke and Hilton's (2015) call for a tool that can identify the knowledge, skills, and attitudes necessary to address a project. By creating disciplinary profiles similar to those in Chapter 4, we can identify disciplinary domains and capabilities. These profiles can offer insight into available expertise and which types of expertise are relevant to a given project. This alignment of disciplinary profiles with research needs can also assist scientists in deciding if a team approach is necessary.

If a team-based solution is required, an understanding of disciplinary character can assist in the identification of disciplinary overlap and gaps. Profile information can be used to critically assess potential team members and choose an optimal combination of complementary expertise to meet a specific research need. The resulting team composition may increase the

chances for the production of scientific knowledge that is relevant to the issue at hand.

Once a team is established, an awareness of these differences can assist in the collaborative process. The early identification of world views that are divergent between disciplines can reduce conflict and tension within the collaboration, as well as improve productive outcomes (Eigenbrode et al., 2007; Stokols et al., 2008). Teams can establish the disciplinary characters of their members per the five factors listed above in order to identify potential points of conflict in advance. This process prompts the proactive identification of topics that necessitate discussion, can focus or frame negotiations, and can promote increased team communication. The increased awareness afforded by the identification of disciplinary differences in this study has the potential, when applied, to improve the collaborative process.

Increased awareness of the differences between scientific disciplines is a fundamental step in creating the “right circumstances” for interdisciplinary collaboration. The identification of these differences may positively impact team development and the collaborative process.

7.2 DESCRIPTION OF SUCCESSFUL NEGOTIATIONS AND OUTCOMES

Recognizing differences between disciplines and resolving conflict is a necessary and challenging process within an interdisciplinary collaboration. Creamer (2004) emphasizes the importance of conflict by stating that “conflict is an element of the relational dynamics of a collaborative relationship that plays an instrumental role in collaborative learning and knowledge construction” (p. 556). In order for conflict to be productive, negotiations must be conducted in order to achieve an accepted level of team consensus that allows forward movement towards a common goal.

In an ideal world, every negotiation between collaborators would result in agreement, or

a harmonious resolution to each conflict. Although agreement may lead to improved productivity, this outcome is unrealistic in collaborative practice. The variation in the opinions, values, and paradigms between collaborators as well as their individual motivations and use for the proposed research make consistent agreement impossible (Lele & Norgaard, 2005; Sonnenwald, 2007). Instead, different types of consensus are achieved that allow continued productivity. The findings from my study demonstrate that a successful negotiation is not dependent upon agreement, but instead, can be described by multiple forms of consensus that move the work forward towards an end goal. In addition, my study reveals a variety of successful outcomes that result from these negotiations.

The meaning and impacts of consensus within a collaborative context vary in the literature (Innes, 2004; Trimbur, 1989). However, John Trimbur's understanding of consensus aligns with my findings. Dr. Trimbur (1989), an expert in composition and writing studies, examined the meaning of consensus with respect to collaborative learning and stated:

I want to concede that consensus in some of its pedagogical uses may indeed be an accommodation to the workings of normal discourse and function thereby as a component to promote conformity and improve the performance of the system. My point will be, however, that consensus need not inevitably result in accommodation.... Consensus represents the potentiality of social agency inherent in group life - the capacity for self-organization, cooperation, shared decision-making, and common action. From a pragmatist perspective, the goal of reaching consensus gives the members of a group a stake in collective projects. It does not inhibit individuality, as it does for those who fear consensus will lead to conformity. Rather it enables individuals to participate actively and meaningfully in group life. If anything, it is through the social interaction of shared activity that individuals realize their own power to take control of their situation by collaborating with others. (pp. 603-604)

Trimbur's observations are significant. He suggests that consensus does not necessarily equate to conformity or unified agreement. Instead, he summarizes that "we need to see consensus, I think, not as an agreement that reconciles differences through an ideal conversation but rather as the desire of humans to live and work together with differences" (Trimbur, 1989, p. 615). In

addition, this lack of reconciliation can actually be productive by offering a critical tool that can further define differences, reveal power relations, prompt continued conversation, and redefine consensus.

The analysis of the EEID team negotiations reflects Trimbur's description and offers distinct examples of consensus. In Chapter 6, the negotiations of three disciplinary characteristics are described in detail and include knowledge base, modes of thinking and research approach, and writing styles and language. These negotiations resulted in varying types of consensus between collaborators, ranging from the disregard of disciplinary input, to consideration and refusal, to integration with and without compromise. The disregard of disciplinary input was observed during negotiations that concerned the appropriate use of disciplinary language. In one instance, a participant suggested that the term "ecology" was not appropriately used within a section of the proposal. Although the suggestion was made, it was not acknowledged publicly and remained unaltered in the final submission. In this case, agreement over language use was not achieved through negotiation. However, work progressed and the proposal was still completed.

An additional level of consensus involves consideration and refusal. This scenario was demonstrated by the negotiation that concerned the incorporation of a social protocol in the proposed study. The collaborators dedicated a substantial amount of time investigating and considering this additional methodology. However, the protocol was ultimately refused due to differences in priorities. This acts as an additional example where unified agreement between parties did not occur, but the negotiation was successful because it resulted in a cohesive methodology.

The third type of consensus involves integration with compromise. Integration of

disciplines is the defining goal of an interdisciplinary collaboration (Bruce, Lyall, Tait, & Williams, 2004; Newell, 2001; Sonnenwald, 2007) and refers to the synthesis, connection or blending of two or more disciplinary factors (Aboelela et al., 2007). Compromise is one method used to achieve integration. This method occurs when two or more parties involved in a negotiation settle differences through the making of concessions. Compromise was evident in the design of the three independent disciplinary protocols. The development of each method was framed by the need to integrate data into and inform a single mathematical model. Therefore, collaborators conceded their preferred disciplinary methods and sampling techniques in order to optimize protocols to inform the model and collaborative research goal. This scenario occurred in the negotiation surrounding the design of the assay protocol. Two collaborators suggested that increased sampling of field ticks in different geographic regions, over time, and across seasons would offer additional and useful data. A third collaborator countered this suggestion by stating that this protocol was outside the scope of the current study and mathematical model. The collaborators compromised in the final design of the assay and agreed to compare ticks from two locations but did not consider time and season. This compromise demonstrates a successful negotiation that obtained partial agreement from the parties that were involved.

The final level of consensus following negotiation involves integration without compromise, or instances when disciplinary integrity is not altered when it is synthesized with another discipline. An example of this scenario was the integration of disciplinary knowledge during the development of the research territory and gaps. Mathematicians, ecologists, molecular biologists and a microbiologist each provided discipline-based literature and background knowledge that was combined in the proposal text. These disciplinary contributions were maintained in an unaltered form. They were used to describe a system and identify gaps in

knowledge throughout that system. The vast majority of knowledge suggestions made by each collaborator were accepted and unaltered, leading to high levels of agreement. This successful negotiation contributed to the productive development of the proposal and demonstrates the more ideal end of the consensus spectrum.

The findings described above demonstrate that unified agreement between all participants does not occur in every negotiation. Despite occasional disagreement, work progressed and goals were achieved. My study demonstrates that consensus does not equate to agreement. Instead, consensus relates more to a collaborator's desire to participate and be productive than their desire to adamantly uphold disciplinary ideals or consistently reach a harmonious outcome. This scenario allows a team to remain productive even when negotiations may not result in agreement.

The success of negotiations conducted by the EEID team can be defined not only by progressing towards goals, but also by the goals that are achieved. Diane Sonnenwald, a prominent researcher in collaboration and technology design, suggests a variety of ways to demonstrate interdisciplinary success. First, Sonnenwald (2007) states that "the creation of new scientific knowledge, including new research questions and proposals as well as new theories and models" is an important result of a successful collaboration (p. 668). She also suggests that the development of new tools or the improvement of existing tools equates to interdisciplinary success. As discussed in the literature review, scholars have attempted to measure this creation of knowledge and productivity by associating interdisciplinary success with an increase in publications, patents, and citation counts for collaborative teams compared to individuals (Glanzel, 2002; Wuchty et al., 2007). Additional outcomes from an interdisciplinary collaboration that act as measures of success include career advancement, educational changes,

and increased institutional support (Jonathon N. Cummings & Kiesler, 2003; Sonnenwald, 2007; Stokols, Harvey, Gress, Fuqua, & Phillips, 2005; Stokols et al., 2008). This literature demonstrates that the successful negotiation of disciplinary differences by a collaboration can lead to numerous productive outcomes. The findings from my study both support and add to this literature.

The most obvious outcome that resulted from the successful negotiations conducted by the EEID team was the research proposal. As discussed in Chapter 6, the team produced and submitted a proposal that was compliant with all National Science Foundation (NSF) established guidelines presented in both the Grant Proposal Guide (GPG) and Request for Proposals (RFP). In addition, the team strategically addressed the reviewer comments that were received on the prior submission. Beyond successfully achieving the goal of proposal production, the team experienced other productive outcomes that demonstrated the success of the negotiations and collaboration. Jim, one of the ecologists on the team, emphasized the importance of interdisciplinary collaboration for his career:

I think it is important for both tenure and collegiality among your peers to collaborate, and I think the fact that [Anne] and I collaborate strengthens my role in my department and my ties to [my university]. It looks good, I think, in the eyes of the administration that we are collaborating and I think there're also... circles that value interdisciplinary collaboration. Showing that you can do this kind of work... is important for my overall portfolio. (Jim, interview, October 10, 2014)

In addition to career advancement, the team further improved and formalized their research plan through successful negotiations. Mike suggested that, regardless of funding outcome, collaborative proposal development “helps solidify ideas and develop new ideas” (Mike, interview, October 23, 2014). In addition, the team received more favorable reviews on the 2014 submission compared to the 2013 submission.

An additional outcome of the collaboration was the continued establishment of

relationships. Anne, the Principal Investigator (PI) for the effort, stated that the work continues “the relationship I have with the South Africans... it is helpful to tie all the different ideas together very formally... [and] just really continues to forge the relationships I have with all of the people on this grant” (Anne, interview, October 15, 2014). In this case, successful negotiation spurs continued collaboration, which offers the team members more collaborative practice and opportunity to learn other disciplines.

The EEID team conducted numerous successful negotiations and was rewarded with multiple productive outcomes. However, even with this success, the team experienced a few barriers. For instance, time was a limiting factor and truncated negotiations. Laura Bronstein (2003) refers to time constraints as a structural barrier to collaboration. Pressing deadlines, as was the case for the EEID team, can halt negotiations before a final resolution can be achieved. For example, multiple suggestions to correct the use of disciplinary terms went unaddressed in the EEID proposal. This was likely due to suggestions being made within 12 hours of the submission deadline, which resulted in inadequate time to consider and implement the suggested changes. An additional and prominent barrier was the fact that inadequate information was provided by the NSF with respect to research expectations and the review process. This issue limited the team’s ability to adequately tailor the proposal to agency needs and predict reviewer priorities, which contributed to a negative funding outcome. This issue is examined in detail in the following section.

Although funding was not awarded, I argue that the EEID team was highly successful both in their negotiations and in the outcomes achieved. My study offers insight into the negotiation process and that different types of consensus, with or without collaborator agreement, still lead to productivity. Therefore, collaborators should be aware that agreement is

not necessary for successful collaboration and dissent can be productive. In addition, the success of a collaborative effort should be measured not by the award of funding, but by a variety of outcomes and the achievement of goals.

7.3 IMPLICATIONS FOR THE AGENCY SOLICITATION AND REVIEW PROCESSES

This study not only informs the interdisciplinary and collaborative processes, but also informs the agencies and reviewers who interact with interdisciplinary proposals. Cooke and Hilton (2015) call for increased research on the funding process with respect to interdisciplinary solicitations and peer reviews. These scholars realize that soliciting this type of proposal is a relatively new trend that has been gaining momentum since the early 2000s (Cooke & Hilton, 2015; Stipelman et al., 2014). This surge is forcing the need to re-evaluate the funding system. An interdisciplinary and collaborative endeavor adds increased complexity to the solicitation and peer review processes compared to those conducted for a unidiscipline or individual proposal effort. These complexities need to be better understood in order to effectively request proposals and award funds to those that have the highest chance for successful execution and knowledge creation.

Although the funding system is expansive and involves many stages, decision processes, and parties, I am focusing on the NSF solicitation and peer review processes due to their direct relation to my findings. The NSF solicitation process is accomplished through three mechanisms that include program descriptions, program announcements and program solicitations (National Science Foundation, 2014b). All of these mechanisms provide guidance for proposal

development as demonstrated by the analysis of the RFP, formally referred to as a program solicitation, in Chapter 6.

The goal of a solicitation is to offer an appropriate level of guidance that prompts the development of viable solutions to a scientific issue. Creating an effective solicitation that achieves this goal is a challenging endeavor, particularly when interdisciplinary work is involved. First, an agency must decide if interdisciplinarity is necessary and cost effective. The integration of multiple disciplines may enable a team to address a highly complex issue or maximize the return on a financial investment (Cooke & Hilton, 2015; Sonnenwald, 2007; Stokols et al., 2008). In contrast, a diverse team may not be required to address certain issues, could decrease productivity, or negate potential benefits in some other way (Cooke & Hilton, 2015; J. N. Cummings, Kiesler, Bosagh Zadeh, & Balakrishnan, 2013; Vermeulen, Parker, & Penders, 2010). Agencies have to weigh the costs and benefits of interdisciplinary work. To do this, they have to be informed and carefully consider the nature of the scientific issue to determine an appropriate approach and scale for the research (Cooke & Hilton, 2015).

Once the agency decides on an area of research and potential types of solutions, it must convey the needs and expectations in the RFP. Cooke and Hilton (2015) discuss the challenge associated with this task:

Agency leaders and staff experience a tension between providing clear guidance (which may become too prescriptive) and encouraging flexible responses from scientists, based on their particular research contexts and capabilities. In addition, agency employees sometimes lack understanding of team science processes and outcomes. As a result, they sometimes develop public announcements that include vague language about the type of collaboration and the level of knowledge integration they seek in the desired research... If the funder is soliciting interdisciplinary or transdisciplinary proposals, then these announcements may lack sufficient guidance to facilitate the deep knowledge integration that is required to carry out such research. (p. 203)

My study confirmed the existence of this tension and the need for improved guidance in certain

solicitations. The EEID solicitation required an interdisciplinary solution. The RFP only offered high-level guidance for the acceptable focus of the research area and examples of potential methods. Minimal guidance was offered with respect to which disciplines should have been included and the level of disciplinary integration that was expected. The EEID team consumed this information and designed their study to include specific disciplines that, in their opinion, best answered the NSF's call for a research solution. Unfortunately, as discussed earlier, the reviewers questioned the scope of the project and did not believe that the team was interdisciplinary. This outcome hindered the team's ability to receive funding.

This conflict reveals that the EEID Program needs to better define their expectations for an interdisciplinary solution and convey those through the RFP. The NSF clearly admits that the definition of the term interdisciplinary is complex and debatable (National Science Foundation, 2015b). However, the agency uses the National Academies' (2004) working definition as a baseline:

Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice. (Committee on Facilitating Interdisciplinary Research, 2004, p. 2)

This definition is broad and offers the agency, researchers, and reviewers a great deal of flexibility in deciding what constitutes an interdisciplinary solution. Perhaps a more precise definition of both "discipline" and "interdisciplinarity" should be developed in order to provide better guidance to all parties involved in the proposal process.

The development of definitions can be NSF wide or specific to the needs of each program. In order to create definitions of "discipline" and "interdisciplinarity" that meet NSF and program needs, the character of each scientific field and the differences between them must

be understood. As discussed earlier, my study demonstrates a method to describe disciplines and obtain this insight. Once determined, a characterization of disciplines can enhance the agency's ability to determine the best type and ideal scope of an interdisciplinary solution. This insight can also assist in creating a precise definition of and expectations for interdisciplinarity, which should be incorporated into program solicitations. This incorporation can enhance the efficiency and success of the solicitation process by better guiding the development of collaborative teams and increasing the likelihood that they produce an appropriate interdisciplinary solution. In addition, the improved RFP would offer more structured guidance to reviewers in their evaluation of proposals.

An improved and more precise solicitation process may result in the receipt of proposals that better meet program priorities. However, this does not alleviate the issue that the program will still receive far more proposals than current funding levels can accommodate. A structured and effective process of peer review that awards funding to those teams that have the highest chances of success is essential. The NSF has dedicated substantial effort to establishing an effective peer review process. This study demonstrated that the NSF merit review process may require modification when dealing with interdisciplinary proposals.

In general, once the NSF receives a submission and determines that all basic criteria are met, the proposal is routed to the appropriate program officer for initial review. If acceptable, he or she identifies three to ten "peers" to evaluate the proposal. These peer reviewers are not affiliated with the NSF and are selected from a variety of sources including previously identified experts in a field, through citations made in the proposal, and through recommendations made by the researchers. These individuals are chosen according to multiple criteria. An individual should have specialized knowledge of a field involved in the proposal that enables them to

evaluate competence and intellectual merit. The reviewer should also have a generalized understanding of the field to evaluate the broader impacts of the research. He or she should understand the scientific infrastructure and related educational activities in order to evaluate the project's contributions. Finally, the team of reviewers should be diverse and represent different ages, organizations, and geographic locations. Once identified, the peer reviewers use the RFP and the merit review process, as discussed in Chapter 6, to evaluate the proposal and justify a rating. The ratings and evaluations are considered by the program officer and a recommendation for funding may or may not be made to the agency (National Science Foundation, 2014b).

Peer review is an established but still debated method of evaluation. Critics of peer review suggest that the method leaves too much room for bias, subjectivity, and inconsistency (Kassirer & Campion, 1994; Lee, Sugimoto, Zhang, & Cronin, 2013; Mitroff & Chubin, 1979). However, peer review has potential benefits if well executed. The NSF attempts to access these benefits by rigorously choosing reviewers to reduce conflicts of interest, agency and reviewer bias, and political influence. In an ideal situation, reviewers can offer useful criticisms that when addressed, can lead to improved research designs. In addition, these peers should be able to predict the viability and significance of proposed research (Ware, 2008).

The selection of reviewers and the review process can be effective when dealing with single discipline efforts. However, this evaluation method is problematic when applied to an interdisciplinary proposal. J. Britt Holbrook (2013), a researcher in the philosophy of science, explains:

Disciplines define peers, and peer review is often designed to uphold disciplinary standards – of rigor, of method, of subject matter, and generally of what counts as good research within a discipline. When a piece of research is subject to peer review, then, it typically means that disciplinary standards will determine whether it passes muster to be published (in the case of a manuscript submitted for publication) or to be funded (in the case of a grant proposal). If peer review depends on disciplinary standards, then how is it

possible to review proposals that go beyond disciplinary bounds? (p. 7)

The identification of this issue has led to a surge in research concerning the peer review process and its use in evaluating interdisciplinary products. Scholars have identified a variety of challenges that need to be addressed in order to effectively and appropriately evaluate this type of research (Cooke & Hilton, 2015; Frodeman & Briggles, 2012; Holbrook, 2013; Holbrook & Hrotic, 2013; Huutoniemi, 2013; Rons, 2013).

Holbrook (2013) raises the question of who should count as a peer in reviewing an interdisciplinary effort. In the case of the EEID proposal, nine primary disciplines were represented. The three NSF reviewers could not have adequately represented all of these fields and as a result, disciplinary experts were tasked with evaluating material that was not within their expertise. These reviewers may also lack interdisciplinary experience and therefore do “not have sufficient breadth of knowledge or perspective to evaluate the integration and interaction of disciplinary or methodological contributions of an interdisciplinary proposal” (Cooke & Hilton, 2015, p. 207). Finally, reviewers may prioritize their disciplinary norms over the others that are represented in a proposal. This natural and established tendency reduces the emphasis placed on the evaluation of disciplinary integration as Katri Huutoniemi (2013) explains:

The most common approach to the assessment of interdisciplinary research has been to prioritize disciplinary standards, premised on the understanding that interdisciplinary quality is ultimately dependent on the excellence of the contributing specialized components. This view treats interdisciplinary research as one more form of the general division of labor in the production of knowledge. (p. 3)

The disciplinary focus and structure of the peer review process may require modification for the purpose of evaluating interdisciplinary proposals.

The findings from my EEID study reveal additional issues with the NSF review process. There was significant variability between each review of the 2014 submission and between

different yearly submissions. This inconsistency between peer reviews has been observed before. Two neurologists, Peter Rothwell and Christopher Martyn, demonstrated that the reproducibility of reviewer assessments was no better than that which occurred by chance (Rothwell & Martyn, 2000). The incorporation of additional disciplines exacerbates this issue, making reproducibility even harder to attain. This extreme variability creates a challenging situation for researchers.

Scientists base the development of their proposals off of agency priorities that are described in the RFP, websites, and other limited sources. The researchers work under the assumption that their proposal will be assessed according to these priorities. However, independent reviewers do not necessarily represent all of the agency's values and will, often times, impose their own biases and subjectivity. This creates inconsistency and a significant disconnect between the agency and researchers, preventing their ability to accurately identify agency priorities and predict the success of a research solution. Also, if consistent review and the award of funding essentially occur by chance, why should researchers invest so much time and effort into revising proposals?

The findings from the EEID study suggest that a lack of agency guidance, poor determination of expectations, and discipline-centric reviewers lead to unstructured and inconsistent reviews. To improve the consistency of the review of interdisciplinary proposals, the NSF may have to offer additional or more precise guidance to disciplinary reviewers. As discussed earlier, better determination of interdisciplinary definitions and expectations by the agency can frame reviewer evaluations. In addition, more explicit review criteria and guidelines pertaining to disciplinary integration may limit the introduction of reviewer subjectivity. These criteria could align with a new requirement for an additional section in the proposal that

describes the interdisciplinarity of the effort. The authors could rationalize their approach by identifying the benefits of integrating disciplines over using a unidisciplinary design. This section could also be a site where the plans for the management and practical execution of the interdisciplinary research are described. Cooke and Hilton (2015) offer additional suggestions for the content of this new section, which include specific plans for communication and coordination, training, quality improvement, and budget allocation. Finally, formal reviewer training on interdisciplinary evaluation and adherence to guidelines may also improve outcomes.

Beyond providing additional guidance, the method by which reviewers are selected may need to change for the evaluation of interdisciplinary proposals. Reviewers that demonstrate interdisciplinary experience and an understanding of knowledge integration may be required. Unfortunately, the review process will always be challenging and complex. However, the evaluation of interdisciplinary proposals is an increasing need and has unique requirements compared to single discipline products. Additional research is therefore necessary to further evaluate and implement potential improvements.

7.4 INTEGRATING DISCIPLINARY DIFFERENCES AND COMPLICATING THE PROPOSAL GENRE

The analysis of the EEID team and their collaborative development of a proposal informed areas other than those described above. One such area involves our current understanding of genre and how interdisciplinarity can complicate this understanding. To appreciate this complexity, we can examine genres through a communities of practice framework (Lave & Wenger, 1991; Wenger, 2006). Communities of practice and genres have a complex mutual relationship, each affecting the other. The examination of this relationship reveals how

genres function within a discipline as tools to accomplish a given action and in turn, to shape and mediate the community (Yates & Orlikowski, 1992). Scientific communities of practice, or disciplines, have developed and depend on genres to productively create knowledge and enable learning. Genres support the very existence of these communities of practice by representing their domain and identity through the embodiment of community values, norms, goals, and knowledge. In addition, genres enable community interaction and the development of relationships by acting as a method to convey cultural information between members. This process, by means of genres, thus allows knowledge to be managed and learning to occur. Finally, genres allow communities of practice to practice. Genres are community tools that are socially constructed through member experience and recurring situational need. Thus, genres are a mode of practice, as action themselves through persuasion and in the action they induce in audience response.

Genres and their associated scientific disciplines are tightly aligned, each molding the other to optimize the achievement of community specific goals. As discussed in Chapter 5, this genre knowledge extends past a single form of discourse and involves an understanding of genre ecologies as well. Therefore, each discipline uses highly specialized genres and individuals possess specific genre knowledge. Interdisciplinarity complicates this understanding of the research proposal genre.

Each discipline represented by the EEID team had genre knowledge specific to their proposal subgenre and its ecology. The team therefore had to negotiate and integrate this specialized knowledge into a single cohesive proposal that appealed to a varied audience. As discussed in Chapter 5, the resulting EEID proposal maintained the genre elements of a research proposal, and was therefore recognized as an example of this discourse. However, the EEID

proposal could not be considered a member of a disciplinary subgenre due to its incorporation of multiple disciplines' norms, values, approaches, language, and more. This situation raises a variety of questions. Can an interdisciplinary proposal be categorized as a genre? Are the contexts of each interdisciplinary proposal too unique to qualify this discourse as a genre? Or, are these proposals an emerging or new type of genre?

Genres occur on a continuum as explained by Carsten Østerlund (2008), a researcher of organizational and knowledge management:

Genres then are neither formal types that can be repeated indefinitely, nor are they formless purely momentary, and contextual conjectures. They constitute socially recognized types of communicative practices that over time become organizational structures through organizational members' habitual use in recurrent situations. (p. 9)

Interdisciplinary proposals fall closer to the momentary end of the continuum. Interdisciplinary teams come together to address specific and often novel issues. The composition, scientific focus, and approaches of these teams can be highly dynamic and dependent on changing research needs. The EEID team demonstrated variability even between the 2013 proposal submission and the 2014 resubmission. Some participants left the team while others were added, new disciplinary approaches were negotiated, and different sets of knowledge were integrated for the 2014 proposal. This variability suggests that each time an interdisciplinary proposal is developed, the context, negotiations, and integrated product are unique.

Within young interdisciplinary collaborations, the variability described above prevents the recurrence of the plastic communicative form and function of a proposal. This prevents the discourse from being classified as a proposal subgenre. However, this research proposal is not entirely unique and formless as it maintains the common elements of the genre. In this case, a research proposal created by an interdisciplinary team may be considered a boundary genre.

Susan Popham (2005), an expert in the rhetoric of science, describes these genres as follows:

[Boundary genres] show a commonality of knowledge, vocabulary, and methodology across professions, even though they may be used for differing audiences, in differing formats, and for a variety of purposes. And as boundary genres, these forms are heteroglossic in voice and authorship, flexible enough for a variety of purposes and yet stable enough to be recognized and used in both local as well as national communities. (p. 296)

A certain level of plasticity and individuality can be expected in a boundary genre, which accommodates both the variability and common genre elements described earlier.

Interdisciplinary groups that regularly practice together and stabilize their domain can become a community of practice. At this point, certain boundary genres may develop into a new interdisciplinary genre. For example, Østerlund (2008) examined a whiteboard used by doctors and nurses to track Emergency Room patients. He identified this whiteboard as a boundary object that occurred between multiple communities including the doctors, nurses, patients, and relatives. These communities negotiated their different expectations and needs over time and as issues emerged. This process led to the development and continued modification of a whiteboard genre (Østerlund, 2008). This example demonstrates that discourse occurring in the boundaries between communities can become a recognized genre. Interdisciplinary genres can also be flexible but do require some level of stability in participants, domain, and purpose in order to recur. Should the EEID team continue to pursue and formalize their community of practice, they may transition the proposal from a boundary genre to a new interdisciplinary proposal subgenre.

The EEID proposal complicates the disciplinary focus of genre and challenges the accepted level of rigidity in its form and function. Additional research into genre within an interdisciplinary context may offer insight into how genres develop and new ways that they may be defined.

7.5 INFORMING RESEARCH ON METHODOLOGICAL DESIGN

The EEID study also informed the research surrounding methodological design. Scholars have dedicated a significant amount of time to defining different methodological approaches and mapping the challenges and benefits of each. This is done with the hope of improving the design of methodologies so that they address research questions more effectively and produce valid data. However, research on the development and description of interdisciplinary methods is quite limited. Although not technically a mixed methods approach, research concerning this paradigm may effectively inform interdisciplinary research design.

Scientific methods are generally categorized under three research paradigms that include quantitative, qualitative, or mixed methods designs (R. B. Johnson, Onwuegbuzie, & Turner, 2007). Briefly, in quantitative research, an individual uses numerical data and statistical analyses to describe trends and the relationships between different variables. This form of inquiry primarily addresses narrow and measurable aims and hypotheses (Creswell, 2012). Qualitative methods rely on the analysis of words or images to explore themes and phenomena. This type of research is more subjective because the researcher interprets the meaning of the data (Creswell, 2012). The definition of mixed methods is a bit more complex and contested, but generally requires a combination of quantitative and qualitative methods.

Burke Johnson and Anthony Onwuegbuzie, experts in educational research, and Lisa Turner, an experimental psychologist, teamed together to survey the status of the field of mixed methods. These researchers recognized the growth and importance of this approach, but also observed inconsistencies in its definition. R. B. Johnson et al. (2007) performed an extensive literature review, coding analysis, and discussions with subject matter experts to trace the history, determine the definition, and identify issues pertaining to mixed methods. Based on this

analysis, Johnson et al. (2007) offer the following definition:

Mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches (e.g., use of qualitative and quantitative viewpoints, data collection, analysis, inference techniques) for the broad purposes of breadth and depth of understanding and corroboration... A mixed methods study would involve mixing within a single study; a mixed method program would involve mixing within a program of research and the mixing might occur across a closely related set of studies. (p. 123)

The mixing of these approaches can occur on a continuum and therefore be qualitative dominant, quantitative dominant, or have equal status (R. B. Johnson et al., 2007).

The mixed methods approach has numerous potential benefits. Kathleen Collins, Anthony Onwuegbuzie, and Ida Sutton (2006), a team of educational researchers, published a paper discussing the use of mixed methods in education. These authors identified a variety of reasons to use the approach. First, the conduct of mixed methods research allows for participant enrichment. Qualitative and quantitative techniques can be combined to identify participants and in turn, optimize the sample by increasing recruitment and ensuring the appropriate selection. Second, the mixed methods approach enables a researcher to assess the appropriateness or utility of instruments due to an increase in available methodological solutions. The third benefit involves treatment integrity, or the improved ability to assess the fidelity of interventions and treatments from different angles. Finally, a mixed methods approach offers significance enhancement by “enhancing researchers’ interpretations of data. A researcher can use qualitative data to enhance statistical analyses, quantitative data to enhance qualitative analyses, or both” (Collins, Onwuegbuzie, & Sutton, 2006, p. 84).

Although many benefits exist, the mixed methods approach can be problematic. These studies can take additional time and effort to design and coordinate. In addition, the studies require expertise in qualitative and quantitative design through all phases of a study (Collins et

al., 2006; Teddlie & Tashakkori, 2003). Collins et al. (2006) elaborate on the difficulties that arise from this situation:

A researcher with more of a qualitative orientation likely would find it more difficult to design the quantitative component of a mixed-methods study than would a researcher with a more quantitative orientation, and vice versa. Another reason stems from conflicts among researchers within a mixed-methods team regarding the most appropriate methodology to use. (p. 68)

The definition, benefits, and challenges associated with a mixed methods approach are strikingly similar to that of an interdisciplinary approach. However, according to the definitions above, the EEID team did not create a mixed methods design because their techniques fell under the quantitative paradigm. Instead, Janice Lauer's initial definition of multimodal is useful to describe the EEID research design. Applied here, a multimodal approach can be understood as the use of various methods stemming from different disciplines to more thoroughly examine a research topic (Lauer & Asher, 1988). The term multimodal has since taken on a different meaning in the literature, leaving this combination of approaches without a definitive name. The many terms used to describe the use of multiple methods, including triangulation, multimethodology, and mixed research, all tend to trace back to the combination of quantitative and qualitative methods (Esteves & Pastor, 2004; R. B. Johnson et al., 2007). Therefore, I propose the term of integrated methods to describe the synthesis of multiple methods stemming from different disciplines that all fall under a single research paradigm. This term also accommodates differing levels of integration of methods that may be achieved by separate interdisciplinary teams.

Research on the development and definition of integrated methods is extremely limited. Kara Hall and her team represent a few scholars that have addressed the integration of "discipline based lines of inquiry" (p. 421). This research offers a general description of the

cognitive and language processes a team must perform to integrate disciplinary research designs (Hall et al., 2012). However, this research is focused on group dynamics and organizational behavior, which limits the scope of the study. Additional research is needed to specifically examine methodological integration across disciplines, how negotiations occur and what this integration looks like.

The results from my study demonstrate that the integration of disciplinary methods is akin to the development of a mixed methods approach. Through numerous negotiations, the team designed an innovative methodological approach to examine a system level issue. The team proposed the execution of three independent, yet complementary, disciplinary methods. In turn, the team would apply the data resulting from these protocols to a single analytical tool, the mathematical model. This novel combination of disciplinary methods would allow the team to effectively examine the system of interest from multiple angles and provide greater insight into numerous confounding factors. This approach is superior to a unidisciplinary approach. The application of a single disciplinary method would have produced isolated data that inaccurately represented the infectious disease system.

The assumption that the integration of quantitative techniques, regardless of discipline, is straightforward is absolutely incorrect. Instead, this integration is equally as complicated, beneficial and problematic compared to a mixed methods approach. First, the level of disciplinary integration occurs on a continuum, similar to that of quantitative and qualitative protocols in mixed methods. The EEID study demonstrated that an interdisciplinary design does not require complete methodological integration. Three disciplines maintained and executed unidisciplinary protocols under the same study. Then, the data resulting from these protocols were integrated to inform a mathematical model. This example suggests that the level of

integration of disciplinary methods occurs on a continuum and is dependent upon the fields involved and the defined research need.

With respect to benefits, the EEID team designed an innovative approach that optimized their sample. This was accomplished by using four protocols that increased the types and quantity of data collected. The team could therefore gather appropriate data and gain insight across multiple facets of the system. The EEID team's approach also enabled the accurate and appropriate choice of methods. The team conducted negotiations to select and integrate the best methods across multiple disciplines to meet the research need. In addition, the EEID research design benefitted from "treatment integrity." The mathematical model used data from three separate disciplinary sources and combined them to predict risk. Three independent sources of data reduced bias towards one aspect of the system and improved the integrity of the model. Finally, the EEID interdisciplinary approach was similar to mixed methods in that the significance of the findings was enhanced. The depth and breadth of understanding of the infectious disease system was increased through the careful integration of the four protocols.

Although not technically a mixed methods design, the EEID research design received similar benefits. The development of the methodologies also experienced the same challenges. Negotiation and development of the proposed design took a significant amount of time and effort. Additionally, the process required expertise in multiple disciplines and an ability to communicate this expertise across different audiences to not only create three complementary protocols, but also integrate these into a fourth modeling method. Finally, the team had to come to some level of agreement with respect to the type of methods used and how they fit together to inform the research need. The EEID team effectively worked through these challenges, but the process required dedication by each collaborator.

The EEID study offers initial insight into the interdisciplinary development of research methods and the resulting level of integration. In addition, this research suggests potential benefits and challenges associated with an interdisciplinary approach, all of which align with a mixed methods analysis. Further examination of interdisciplinary research using mixed methods scholarship may enhance our understanding of the definition of an interdisciplinary approach and the associated costs and benefits. In turn, this insight may improve a researcher's ability to critically choose disciplinary methods and their level of integration in order to effectively and innovatively address a research need.

7.6 AREAS FOR FUTURE RESEARCH

This study produced an abundance of data and offered multiple insights relating to interdisciplinary collaboration, the funding process, the proposal genre, and methodological design. However, the study had a small-scale approach and was conducted on a single interdisciplinary and collaborative team. This small participant pool and focused context reduces the generalizability of my findings. This approach may also limit the comprehensiveness of my data as specific disciplinary and proposal development features may not have been experienced by this team. My experience in the field of proposal development mitigated these issues. However, extending this research to additional interdisciplinary and collaborative teams would reinforce my findings and add validity to my conclusions.

Beyond the need for replication, this study opened numerous avenues for additional research. Disciplinary characteristics were not the only source of differing values, norms, and knowledge between the members of the collaborative team. The participants embodied the characteristics of additional social worlds such as gender, ethnicity, geographic location,

institutions, and professional level. Similar to discipline, differences between these social worlds were negotiated through the EEID proposal. Analysis of these worlds, the negotiations, and final outcomes may offer additional insight into the complexity of proposal development and the collaborative process.

Additional research concerning the proposal solicitation and review processes is also necessary in order to make the conclusions from this study more robust. A similar analysis could be conducted on other boundary objects in the funding system. Analysis of the program solicitation and the negotiations conducted between the program officer and NSF stakeholders would offer insight into how research expectations are created and conveyed. The boundary object analysis of the EEID proposal and reviewer comments through the NSF review process would offer excellent insight into the factors that impact proposal ratings and funding outcomes.

The interdisciplinary and collaborative process required to develop a research proposal is exceedingly complex, leaving ample room for additional research.

7.7 FINAL THOUGHTS

This study offers some insight into the process of interdisciplinary and collaborative proposal development. My findings highlight the need to increase disciplinary awareness to improve the collaborative process. Additionally, funding agencies need to modify their established solicitation and review processes to accommodate the unique challenges associated with interdisciplinary research. This study is by no means conclusive and has succeeded in identifying many more avenues for research, which over time, will hopefully lead to improvements in the funding environment for interdisciplinary scientific research.

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APPENDIX A

IRB APPROVAL LETTERS



OFFICE OF THE VICE PRESIDENT FOR RESEARCH
Physical Address

4111 Monarch Way, Suite 203
Norfolk, Virginia 23508

Mailing Address

Office of Research
1 Old Dominion University
North, Virginia 23529
Phone(757) 683-3460
Fax(757) 683-5902

DATE: October 3, 2014

TO: Louise Phelps

FROM: Old Dominion University Institutional Review Board

PROJECT TITLE: [656282-3] Interdisciplinary and collaborative design of methods in scientific research grants: Negotiation through boundary objects

REFERENCE #: 14-161

SUBMISSION TYPE: New Project

ACTION: APPROVED

APPROVAL DATE: October 3, 2014

EXPIRATION DATE: September 18, 2015

REVIEW TYPE: Full Committee Review

Thank you for your submission of New Project materials for this project. The Old Dominion University Institutional Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Full Committee Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this committee. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this committee.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of September 18, 2015.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Adam Rubenstein at 757-683-3686 or arubens@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Institutional Review Board's records.



OFFICE OF THE VICE PRESIDENT FOR RESEARCH
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Norfolk, Virginia 23508

Mailing Address

Office of Research
1 Old Dominion University
Norfolk, Virginia 23529
Phone(757) 683-3460
Fax(757) 683-5902

DATE: September 28, 2015

TO: Louise Phelps

FROM: Old Dominion University Institutional Review Board

PROJECT TITLE: [656282-6] Interdisciplinary and collaborative design of methods in scientific research grants: Negotiation through boundary objects

REFERENCE #: 14-161; 15-174

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED

APPROVAL DATE: September 28, 2015

EXPIRATION DATE: September 17, 2016

REVIEW TYPE: Full Committee Review

Thank you for your submission of Continuing Review/Progress Report materials for this project. The Old Dominion University Institutional Review Board has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Full Committee Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this committee. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this committee.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of September 17, 2016.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

If you have any questions, please contact Adam Rubenstein at 757-683-3686 or arubens@odu.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within Old Dominion University Institutional Review Board's records.

APPENDIX B

INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT OLD DOMINION UNIVERSITY

PROJECT TITLE: Interdisciplinary and Collaborative Design of Methods in Scientific Research Grants: Negotiation through Boundary Objects

INTRODUCTION

The purposes of this form are to give you information that may affect your decision whether to say YES or NO to participation in this research, and to record the consent of those who say YES. The research will be conducted through multiple modes to include e-mail, Skype, and telephone.

RESEARCHERS

The Responsible Project Investigator is Dr. Louise Phelps, Visiting Scholar, Ph.D., College of Arts and Letters, Department of English. The additional investigator is Laura Paganucci, Graduate Student, M.S., College of Arts and Letters, Department of English.

DESCRIPTION OF RESEARCH STUDY

Several studies have been conducted looking into the subject of collaborations between different disciplines. None of them have adequately explained how these collaborations function, interact, and negotiate in order to work on a common problem.

If you decide to participate, then you will join a study involving the research of grants and other items that act as boundary objects, or an object that functions between and assists collaborative interdisciplinary endeavors. Specifically, this research seeks to understand how you negotiate your disciplinary knowledge with those of your team members to develop research methodologies. In addition, we want to understand how these grants and other tools, such as software systems or statistical analyses, coordinate teams and act as a nexus for negotiation between participating disciplines, institutions, and funding agencies.

If you say YES, then your participation will take place at certain points over a period of three months, from the letter of intent stage to grant submission. During this period, Ms. Paganucci will observe group e-mail correspondence by being cc'd on team e-mail chains and by reading e-mails from previous submission efforts for the proposal under study. She will also read written drafts of grant documents, and observe with note-taking, face-to-face or Skype meetings. Ms. Paganucci also seeks your consent to participate in and voice record two interviews, taking approximately 45 minutes each, and occurring at the beginning and following completion of grant development. Finally, Ms. Paganucci requests examples of federal proposal research plan sections from you. By signing this consent form, you represent the approval of all collaborators involved in the example effort to share the material with Ms. Paganucci. Approximately 30 individuals will be participating in this study.

EXCLUSIONARY CRITERIA

To the best of your knowledge, you should not have plans to leave the collaboration prior to grant submission, which would keep you from participating in this study.

RISKS AND BENEFITS

RISKS: If you decide to participate in this study, then you may face a risk of the release of identifiable information such as name, institution, and personal statements. The researcher tried to reduce these risks by de-identifying all demographic and personal information from collected data through the assignment of a pseudonym. And, as with any research, there is some possibility that you may be subject to risks that have not yet been identified.

BENEFITS: There are no direct benefits for participation in this study.

COSTS AND PAYMENTS

The researchers are unable to give you any payment for participating in this study.

NEW INFORMATION

If the researchers find new information during this study that would reasonably change your decision about participating, then they will give it to you.

CONFIDENTIALITY

The researchers will take reasonable steps to keep private information, such as interview statements, e-mail correspondence, grant drafts, and research plans confidential. The researcher will remove identifiers from the information, destroy voice recordings, and store information in a locked filing cabinet prior to its processing. The results of this study may be used in reports, presentations, and publications; but the researcher will not identify you. Of course, your records may be subpoenaed by court order or inspected by government bodies with oversight authority.

WITHDRAWAL PRIVILEGE

It is OK for you to say NO. Even if you say YES now, you are free to say NO later, and walk away or withdraw from the study -- at any time. Your decision will not affect your relationship with Old Dominion University, or otherwise cause a loss of benefits to which you might otherwise be entitled.

COMPENSATION FOR ILLNESS AND INJURY

If you say YES, then your consent in this document does not waive any of your legal rights. However, in the event of harm arising from this study, neither Old Dominion University nor the researchers are able to give you any money, insurance coverage, free medical care, or any other compensation for such harm. In the event that you suffer harm as a result of participation in any research project, you may contact Dr. Louise Phelps at 757-683-4023, Dr. George Maihafer the current IRB chair at 757-683-4520 at Old Dominion University, or the Old Dominion University Office of Research at 757-683-3460 who will be glad to review the matter with you.

VOLUNTARY CONSENT

By signing this form, you are saying several things. You are saying that you have read this form or have had it read to you, that you are satisfied that you understand this form, the research study, and its risks and benefits. The researchers should have answered any questions you may have had about the research. If you have any questions later on, then the researchers should be able to answer them:

Dr. Louise Phelps; 757-683-4023
 Laura Paganucci; 757-502-5776

If at any time you feel pressured to participate, or if you have any questions about your rights or this form, then you should call Dr. George Maihafer, the current IRB chair, at 757-683-4520, or the Old Dominion University Office of Research, at 757-683-3460.

And importantly, by signing below, you are telling the researcher YES, that you agree to participate in this study. The researcher should give you a copy of this form for your records.

Subject's Printed Name & Signature	Date
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INVESTIGATOR'S STATEMENT

I certify that I have explained to this subject the nature and purpose of this research, including benefits, risks, costs, and any experimental procedures. I have described the rights and protections afforded to human subjects and have done nothing to pressure, coerce, or falsely entice this subject into participating. I am aware of my obligations under state and federal laws, and promise compliance. I have answered the subject's questions and have encouraged him/her to ask additional questions at any time during the course of this study. I have witnessed the above signature(s) on this consent form.

Investigator's Printed Name & Signature	Date
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APPENDIX C
INTERVIEW SCRIPT

Interview:

* Follow up questions or prompts are only used to redirect the focus of the conversation if necessary.

* Time will be tracked

Introduction:

Interviewer: Good afternoon / morning (continue with greeting and express appreciation for agreeing to meet).

I want to remind you that I will be recording this interview for future analysis. I can stop recording at any time upon request. This interview will take approximately 45 minutes.

As we discussed back in our earlier meeting when you signed the consent form, the primary purpose of this study is to observe how you and your team members collaborate to design the methods for the XXX grant proposal, what types of things you bring to the table and negotiate, as well as the tools you use.

Before we start, do you have any questions about the study?

Disciplinary identity: Allow approximately 15 minutes

Interviewer: To start, I want to understand how you identify yourself in relation to your discipline.

Question 1: What scientific discipline do you currently associate with? Is there more than one?

Follow up: Have you always been part of XXX discipline? If not, how did you end up in your current area of expertise?

Question 2: What professional position(s) and associations do you currently hold? Are these positions limited to academia, or include industry as well?

Question 3: What distinctive features, such as methods, values, or writing styles come to mind when you think about your discipline?

Sub questions if necessary: How is a scientist typically trained in or how does he or she become part of XXX discipline?

Question 4: In your discipline, what does success mean? What does success mean to you? (Prompt if necessary: promotion, funding, etc.)

Question 5: How do you fit into your discipline, and how do you differ from other people in your discipline?

Interviewer: Now, I am curious how you consider your discipline different from those of your teammates.

Question 6: Reflecting on what we just talked about, how do you think you and your discipline differ from your teammates working on the XXX grant?

Question 7: Do you think that these differences stem from the fact that you each come from a different scientific discipline?

XXX grant application: Allow approximately 15 minutes

Interviewer: Let's shift gears a little bit. Now I would like to understand a bit more about the XXX proposal that you are working on.

Question 8: What motivated you to work on this grant?

Question 9: What parts of the XXX proposal do you plan on contributing to the most?

Question 10: What do you hope to get out of this grant, awarded or not?

Question 11: What factors do you think are most important in developing the XXX grant?

Follow up: How does the RFP, review criteria, program officer, and other proposal materials impact your thoughts on developing a proposal?

Question 12: What factors are most important to consider in designing the methods for the XXX proposal?

Question 13: Do you have specific methodologies or an approach in mind?

Question 14: What are your thoughts on collaboration to produce a proposal?

Question 15: Have you had experience including multiple scientific disciplines in a collaboration to produce a proposal?

Follow up: What challenges have you faced when working with different disciplines to produce a proposal? Benefits?

Identification of boundary objects: Allow approximately 15 minutes

Interviewer: Let's shift gears one last time. Now, I would like to understand the tools you use when you collaborate with your XXX proposal team.

Question 16: What process do you follow to design a methodology?

Question 17: What resources do you draw from when you design the methods for a research project?

Prompts: people, software, statistics, common experimental protocols

Question 18: Do you feel as though your XXX proposal teammates use similar or different resources?

Question 19: What resources or tools do you use to write a proposal?

Question 20: What types of tools do you use to communicate with your teammates while working on the XXX proposal?

Question 21: What parts of the proposal or aspects of developing a proposal do you work on as a team?

Interviewer: In order to understand how you and your teammates bring your different ideas and knowledge together to create the XXX proposal, I want to look at boundary objects. We discussed this concept in our prior meeting, but let me review just a bit. A boundary object is often an actual object and for our purposes, it is a material thing used by people in their own discipline as well as in a collaboration. Let's take the XXX proposal as an example. Your discipline, XXX, is well acquainted with grants and how to write them. Many other scientific disciplines also use these grants, but each discipline has to write them a slightly different way depending on the field of study, the funding agency, and your aims. So, multiple disciplines recognize and use grants on their own to meet their own needs. In turn, your discipline and others can all come together and work on a single grant. So this object, the grant, exists between your disciplines and as it is created by each of you, it contains elements of all of your disciplines. So the idea is that this object is a physical site where you all can come together and work through and document your different ideas to produce a single research plan. You can think of it as a physical bridge between disciplines. Ultimately, a boundary object can be anything that multiple people recognize and use to communicate and collaborate. An additional example is software, such as MatLab. Each discipline can use it for a variety of applications to serve a specific purpose. People can also come together and use MatLab collectively to come up with a collaborative solution in the software. A final example is statistics. Many disciplines recognize statistical methods, such as an ANOVA or the t-test. Each discipline can manipulate statistics readily and in turn, disciplines can come together and use these methods to create a statistical analysis for a common problem.

Question 22: Do you have a basic understanding of the boundary object concept?

Question 23: What are your thoughts about boundary objects?

Question 24: Can you think of other items that you may use as a boundary object in your work with the XXX proposal team?

Interviewer: Thank you for your participation. Contact me if you have any questions or concerns.

VITA

Laura Emond Paganucci
 Departmental Address:
 Department of English, Old Dominion University, 5000 Batten Arts & Letters
 Norfolk, VA 23529
 (757) 683-3991

Education:

Doctor of Philosophy, English, Old Dominion University, 2016.
 Dissertation: "Collaborative Development of an Interdisciplinary Scientific Research
 Proposal: Negotiation through Boundary Objects."

 Master of Science, Molecular, Cellular and Systems Physiology, Dartmouth College, 2006.
 Thesis: "Brainstem Catecholaminergic Neurons Affect Arterial Pressure and Heart Rate
 at Rest and During Hypoxic Stress."

 Bachelor of Arts, Biology, Bowdoin College, 2002.

Professional Experience:

Proposal Director, AVIAN LLC. 2014-Present.

 Professional Scientific Writer, Private Consultant, 2010-2014.

 Grant Writer, Old Dominion University, 2008-2010.

 Research Assistant, Eastern Virginia Medical School, 2006-2007.

Publications:

Li, Aihua, Emond, Laura, & Nattie, Eugene. (2008). Brainstem Catecholaminergic Neurons
 Modulate Both Respiratory and Cardiovascular Function. In Marc J. Poulin, J. Richard &
 J.A. Wilson (Eds.), *Integration in Respiratory Control* (pp. 371-376). New York: Springer.

 Nobles, Susanne & Paganucci, Laura. (2015). Do Digital Writing Tools Deliver? Student
 Perceptions of Writing Quality Using Digital Tools and Online Writing Environments.
Computers and Composition, 38, 16-31.