THE DAWN OF INNOVATION: AWAKENING INTERDISCIPLINARY COLLABORATION THROUGH BOISE STATE'S GRAND CHALLENGES INITIATIVE

by

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The following individuals read and discussed the dissertation submitted by student Eva Loraine Gaudio, and they evaluated the student's presentation and response to questions during the final oral examination. They found that the student passed the final oral examination.

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DEDICATION

In loving memory of Shane Gaudio, my husband, who was the bedrock of my academic pursuits, and in honor of Sylvia Milner, my mother, whose resilience and support have been my guiding light. Shane, your dedication to my dreams was unparalleled, and Mom, your unwavering support in the face of adversity has been my salvation. Together, you both have shaped my path, and this achievement is as much yours as it is mine.

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ABSTRACT

In Process

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

NOMENCLATURE

σ	The mass of one angel
σ_I	The number of angels per needle point
σ_μ	The number of angels per unit area
$\sigma_{1/\lambda}$	The total mass of angels per unit area
σ_L	The area of the needle point

CHAPTER 1:

INTRODUCTION

1.1 Scientific Discovery for Wicked Problems

Can scientific discovery pave the way for solving society's most complex challenges? In an era where complexities intertwine with every aspect of societal progress, understanding and addressing wicked problems becomes a necessity. A "wicked problem," as described by Rittel & Webber (1973), refers to complex social challenges characterized by their intricacy and resistance to straightforward solutions. These problems, such as those outlined in the United Nations' Sustainable Development Goals (SDGs), are marked by their interconnectedness, and the repercussions ripple through various social systems. Social processes within these challenges are likened to networks, where each action creates a web of effects, underscoring the importance of considering the broad, interconnected systems (Rittel & Webber, 1973). These problems necessitate a comprehensive approach that blends scientific inquiry with innovative policymaking.

This thesis explores how research collaboration can be aided to enable novel insights into these multifaceted issues. Collaborative research teams, especially those that span different disciplines at academic institutions and include community stakeholders, are recognized to produce the highest impact work and most groundbreaking innovations (e.g., Sonnenwald, 2007; Disis & Slattery, 2010; Hart, 2000; Enns *et al.*,

2023; Lieberknecht *et al.*, 2023). Boise State University (Boise State), recognizing the urgency and complexity of local, regional, and national societal issues, is invested in the ambitious Grand Challenges (GCs) initiative. This initiative's multivariate approach, settled as the cornerstone of Boise State's strategic plan, is designed to foster a transdisciplinary culture of research and creative activity. The University's Center of Research and Creative Activity (CRCA) is pivotal in this endeavor, leading the charge by investing in an Interdisciplinary Research Accelerator (IRA) model (LaRosa, 2023a).

Acknowledging the increasing emphasis in management and organizational studies on researching teams addressing grand societal challenges (Bednarek *et al.*, 2023, citing George et al., 2016; Harley & Fleming, 2021, p.133), the CRCA has identified the need for comprehensive research evaluating the impact of their researcher support plan. This observation led to the formation of the Social Network Analysis Project (SNAP), asking, "How do the GCs investments change collaborations across campus?"

My thesis, set against this backdrop, aims to describe the structural and relational dynamics among Boise State faculty and staff, focusing on understanding the state of the collaborative environment before and during the GCs investments. By analyzing these dynamics, this research seeks to understand and elucidate how these investments have altered collaborative patterns across campus. This exploration will not only contribute to understanding the immediate effects of the GCs investments but also serve as a foundation for future studies to track ongoing collaboration changes. Additionally, this study aims to highlight areas requiring targeted interventions, thereby enhancing the efficacy of Boise State's GCs' initiative addressing Idaho's wicked prob-

lems, contributing to the global pursuit of SDGs.

Thesis Statement: This thesis posits that through a detailed analysis of the structural and relational dynamics within Boise State University's Grand Challenges initiative, significant insights can be gained into enhancing interdisciplinary collaboration. These insights are crucial for addressing complex societal challenges and contribute to advancing the field of social network analysis in academic settings, thereby informing strategies to optimize collaborative efforts for societal progress.

1.2 Advancing Idaho: The Grand Challenges

The inception of Boise State's GCs initiative can be traced back to 2015 when Jana LaRosa, the Assistant Vice President for Research Advancement and Strategy (AVPR) in the Division of Research and Economic Development (DRED), inspired by institutions like the University of Texas Austin (UT Austin), began contemplating Boise State's own GCs (LaRosa, 2023b, personal communication, September 25). UT Austin's Planet Texas 2050 (PT2050), as analyzed by Lieberknecht *et al.* (2023), exemplifies an innovative, collaborative, interdisciplinary ethos. This interdisciplinary ethos supports researchers in crafting their own thematic roadmaps and provides a useful comparative framework for understanding team dynamics within Boise State's GCs.

In 2019, Boise State's Interim Vice President of Research (VPR) Harold Blackman, Interim Provost Tony Roark, and President Marleen Tromp put out a call to campus asking faculty to send in 2–3-page proposals on what could be theme areas for the GCs (LaRosa, 2023b, personal communication, September 25). They looked at the approximately 150 submissions and then put together five different thematic areas (LaRosa, 2023b, personal communication, September 25) with two primary

challenges: "Resource Nexus for Sustainability" and "Healthy Idaho" (Research and Economic Development, 2024). This process demonstrates the faculty's active role in shaping the GCs, reflecting the relational dynamic and collaborative spirit central to my thesis.

The GCs Resource Nexus for Sustainability and Healthy Idaho addresses global challenges regionally. The Resource Nexus for Sustainability GC embodies SDG goals like access to clean water and sanitation, promoting affordable and clean energy, and fostering sustainable urban and community development (United Nations Department of Economic and Social Affairs, 2024). This initiative integrates various scholarly disciplines and stakeholders, aiming to build resilient urban and rural systems through a collaborative nexus of scholars and practitioners. Similarly, Healthy Idaho GCs are rooted under a public health umbrella, which focuses on the interconnectedness of human, animal, and environmental health (LaRosa, 2023b, personal communication, September 25).

Boise State's strategic plan, "Blueprint for Success 2021-2026," outlines key goals encompassing educational access, research advancement, and community engagement. The GCs initiative, particularly aimed at advancing research and creative activity, intersects with all these goals, showcasing its multifaceted impact on the university's vision (Boise State University, 2024). Notably, Goal 3 specifically highlights the GCs initiative as a pivotal strategy for research advancement (Boise State University, 2024). However, the GCs initiative's influence extends beyond this single goal: it actively contributes to all five goals, embodying the diverse strategies outlined in the blueprint. Throughout this thesis, I will point out some of the ways the GCs initiative not only bolsters research but also synergistically supports the broader objectives

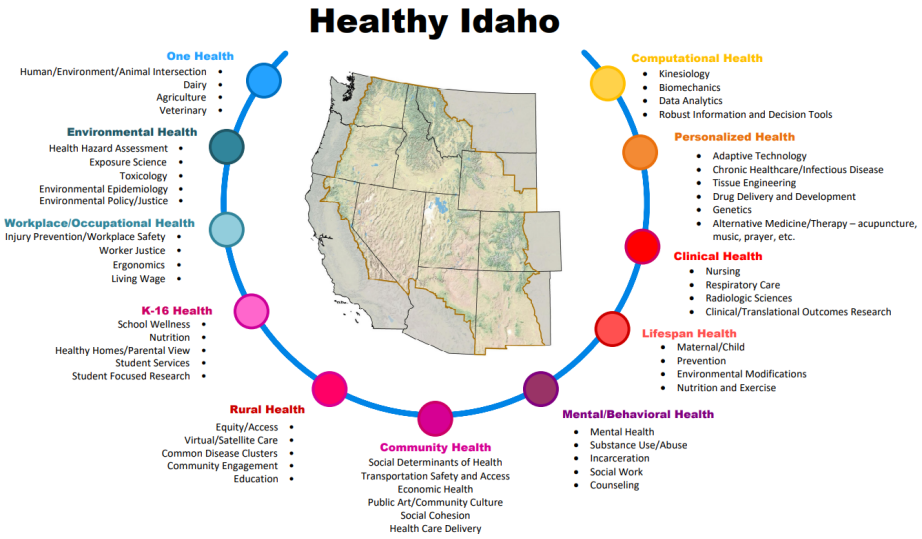

Figure 1.1: The Healthy Idaho GC outlines key areas for collaborative efforts to improve health outcomes across the state. These areas include Public Health, emphasizing the human-environment-animal intersection; Environmental and Workplace Health; K-16 Health, focusing on youth wellness and education; Rural Health, addressing equity and access; Community Health, underlining social determinants; and spans Computational, Personalized, Clinical, Lifespan, and Mental/Behavioral Health. Research teams might explore innovative solutions across these dimensions to foster comprehensive well-being and address the multifaceted health challenges in Idaho's diverse communities.

of Boise State's, thereby playing a crucial role in realizing the university's vision for success. This backdrop of interdisciplinary and collaborative effort within Boise State's strategic framework is pivotal to my thesis, as it underscores how the GCs initiative not only advances research but also supports broader institutional goals.

1.3 Understanding Collaboration: SNAP

SNAP is a research team dedicated to understanding faculty collaboration at Boise State in the context of the impact of the GCs initiative. The team includes staff and faculty across campus, including Anthropology, Philosophy, Human-Environment Systems, the School of Public and Population Health, the Library, and DRED. Additionally, the team includes a graduate student: me. As a member of this project, I have access to this innovative learning experience, an example of the GCs initia-

tive performing Boise State's blueprint goal to improve student success Boise State University (2024).

Several research branches were formed to measure the impact of the GCs initiative's investments. Phase 1 of SNAP moves to characterize research and creative activity at Boise State before and at the start of the initiatives' programs. This thesis details three branches of SNAP: VAMPIRE, CUPID, and LOVE.

Vicken And Many Persons Interview Research Enterprise (VAMPIRE) is a cheeky name for describing the qualitative expertise of SNAP research branch lead, Dr. Vicken Hillis. Tasked with conducting and analyzing informal faculty interviews about collaboration, VAMPIRE asks, "In what ways do faculty at Boise State's conceptualize collaboration beyond traditional metrics such as proposal applications and publications?" and "What diverse forms of collaboration are prevalent among Boise State's faculty, and how do these collaborations manifest in academic settings?" To help answer these questions, chapter three of this thesis thematically analyzes faculty responses from focus groups and semi-structured interviews. The chapter explores themes of academic culture, institutional structures, and interpersonal dynamics, offering insights into the multifaceted nature of collaboration in a university setting.

Collective Understanding of PI Data (CUPID) is a research branch of SNAP that uses social network analysis (SNA) on grant application data to answer three research questions. CUPID asks, "How have the dynamics of grant networks at Boise State evolved, and what factors have influenced this change?" "To what extent have the Grand Challenges initiatives influenced these evolving grant proposal networks?" and "Is it possible to predict the formation and changes in collaborative ties between Principal Investigators (PIs) and Co-PIs within these networks?" Chapter four of this

thesis contains a report on historical grant networks. I describe collaborative grant proposal networks between 2016 and 2020 using network visualizations, whole network metrics, and exponential random graph models (ERGMs) for a comprehensive analysis.

The fifth chapter of this thesis reports on research teams formed out of the GCs initiative. In this project branch, SNAP replicates the mid-point survey by Love *et al.* (2021) to investigate these characteristics in interdisciplinary scientific teams. Budding off VAMPIRE and deemed the LOVE branch, SNAP asks, "How do intensive research collaborations within the GCs initiative evolve and impact the nature of collaborative relationships over time?" It is anticipated that LOVE will survey the team several times over the course of the GCs investments. The LOVE chapter reports the initial survey results, visualizing and comparing various team networks, which provides a dynamic view of interdisciplinary collaboration within the GCs framework.

Through these diverse yet interconnected branches of SNAP, this thesis aims to paint a comprehensive picture of the dynamics of interdisciplinary collaboration at Boise State. The insights gained are instrumental in understanding how such collaborations can be optimized to tackle the wicked problems of our time, aligning with global efforts like the SDGs. In the next chapter, I explore collaboration literature. I examine the literature that details the value of collaboration, defines its various forms in academia, and outlines teaming concerns.

CHAPTER 2:

LITERATURE REVIEW

2.1 The Power of Collaboration in Science

Collaboration is vital for solving complex scientific problems and furthering various political, economic, and social agendas, including thriving democracy, sustainable development, and cultural integration. Collaboration can extend the scope of research projects and foster innovation by providing additional expertise (Sonnenwald, 2007). Disis & Slattery (2010) argues that multidisciplinary research teams have several advantages over single-discipline teams. These advantages include a more extensive knowledge base, wider networks, and the ability to engage in dynamic, connective thinking (Disis & Slattery, 2010). As a result, multidisciplinary teams are better positioned to generate radical innovations Disis & Slattery (2010). Collaboration also increases scientific reliability and success probability by involving multiple perspectives in verifying results (Sonnenwald, 2007). This concept of increased scientific reliability through collaboration is a key consideration in the SNAP project. By examining the nature and outcomes of collaborative efforts at Boise State, this research seeks to identify how collaborative dynamics influence the success and reliability of research projects under the GCs initiative. This rationale also underpins the promotion of collaboration at the university, as it not only advances research quality

but also enhances a scientist's credibility within the scientific community in line with Boise State's blueprint goal 4: fostering a thriving community (Boise State University, 2024). The inclusion of community partners in GC research development also aids in the achieving of goal 4 and aligns with the idea that to effectively tackle society's wicked problems and achieve the United Nations' SDGs, academia must promote and support external community partnership (Rittel & Webber, 1973).

Having established the crucial role of collaboration in advancing scientific discovery, it is pertinent to define what constitutes scientific collaboration. Scientific collaboration is defined as a behavior among scientists that involves sharing meaning and completing tasks toward a common, overarching goal, taking place within a social context (Sonnenwald, 2007). Hart (2000) underscores the value of collaboration in enhancing the quality of academic work. In their study on collaborative publications by university librarians, Hart found that collaborative efforts often result in higher quality outputs than single-authored works (Hart, 2000). This phenomenon is attributed to the diverse expertise, mentoring, and intellectual benefits brought together through collaborative efforts, indicating that multi-authored works tend to undergo more rigorous quality control (Hart, 2000).

Intradisciplinary collaboration, or unidisciplinary (Okraku *et al.*, 2017) or simply disciplinary, is a form of scientific cooperation where participants from the same field contribute and generate knowledge within their specific domain, as noted by Sonnenwald (2007). Moody (2004) describes research specialties within these collaborations as central clusters of scientists instrumental in generating innovative concepts and ideas. Dalton *et al.* (2021) further define a scientific discipline as a distinct field characterized by unique discourses and practices, akin to a specific language code.

This "language," encompassing methodologies, terminologies, and theoretical frameworks, remains largely exclusive to the discipline, providing its practitioners with a framework for focused scientific progress (Dalton *et al.*, 2021).

Interdisciplinary collaborations play a crucial role in addressing global challenges by merging diverse expertise and perspectives, thus enabling a more comprehensive understanding of complex issues. While intradisciplinary collaboration significantly generates knowledge within specific domains, the shift towards interdisciplinary collaborations opens up new avenues for addressing more complex societal issues. Jana LaRosa, the Assistant Vice President for the DRED at Boise State, emphasizes the importance of integrating disciplines (LaRosa, 2023b, personal communication, September 25). She notes that while disciplinary work is valuable for its incremental contributions to specific fields, interdisciplinary work is essential for tackling broader, society-driven questions that single disciplines cannot address alone. This perspective aligns with the growing trend among federal agencies to prioritize interdisciplinary research in funding decisions (Huang *et al.*, 2023; Lyall *et al.*, 2013). Leite & Pinho (2017, p. 31) point out that the increasing focus of funding bodies is on fostering various collaborative arrangements, including partnerships among researchers, cross-institutional collaborations, international and regional agreements, input from peers outside the institution, joint authorship endeavors, programs for visiting scholars, and both interagency and international training groups for research. LaRosa highlights that researchers at Boise State must excel in team-based approaches to capitalize on funding opportunities that demand interdisciplinary efforts (2023b, personal communication, September 25). She points out the need for authentic collaboration between STEM and social sciences, moving away from superficial integrations towards gen-

uinely co-created and co-developed research questions that synergize both domains (2023b, personal communication, September 25). This shift marks a departure from traditional practices where social science elements were often added as afterthoughts to STEM projects; instead, it calls for an equal and integrated partnership from the outset of research initiatives.

2.2 Measuring Interdisciplinary Collaboration

Increasing interdisciplinary and transdisciplinary collaborations is a core goal of the GCs investments. Scientific disciplines must work together to solve complex and large-scale societal challenges like Resource Nexus for Sustainability and Healthy Idaho. Collaborative research is often categorized into three distinct yet interconnected types: multi-, inter-, and transdisciplinary (e.g., Dalton *et al.*, 2022; Sonnenwald, 2007; Lieberknecht *et al.*, 2023). Multidisciplinary research involves various disciplines working in parallel, each contributing their perspective without integrating their efforts (Dalton, Wolff, and Bekker 2021). In contrast, interdisciplinary research signifies a deeper level of collaboration where multiple disciplines converge their methodologies and viewpoints to tackle a common problem (Dalton *et al.*, 2021). Transdisciplinary research transcends traditional academic boundaries by converging research design with external entities such as industry, government, and community stakeholders, thus offering a holistic approach to complex societal issues (Dalton *et al.*, 2022). Understanding these diverse forms of collaboration is crucial for the SNAP project, as it seeks to examine how Boise State's GCs initiative navigates and fosters these varying levels of interdisciplinary cooperation.

Delving deeper into the classifications of collaborative research, Bolger (2021) zeros in on the degree of interdisciplinary research by categorizing discipline dis-

tances. Through a study of three established research centers, the study surveys faculty members on their motivations for joining the centers, their perceptions of interdisciplinary research, and the nature of their collaborative activities. Bolger introduces a novel classification based on the 'distance' between collaborating disciplines: 'within-discipline' collaborations (e.g., between biologists with different specializations), 'short distance' within the same super-discipline (e.g., an engineer collaborating with a biologist), and 'long distance' across distinct super-disciplines (e.g., an ecologist working with a social scientist) (Bolger, 2021). This final categorization distinguishes collaborations spanning 'hard' sciences (natural and applied sciences) and 'soft' sciences (social sciences and humanities), offering a more granular understanding of interdisciplinary research dynamics (Bolger, 2021).

Beyond academic boundaries, expanding our understanding to collaborations involving academia, business, and community groups is pivotal for addressing societal challenges. In this realm, participatory action, a collaborative approach between scientists and community members, values community members' knowledge, experiences, and values, aiming to integrate these into research projects (Sonnenwald, 2007). Its goal is to generate knowledge that leads to effective social action and solves real-life problems, with the effectiveness of the action determined by participants (Sonnenwald, 2007). To demonstrate the effectiveness of participatory action in bridging academic research with real-world application, I summarize two exemplary models: SPECTRUM and PT2050. These initiatives exemplify how collaborative efforts can address societal challenges by integrating diverse perspectives from academia, business, and community groups.

Enns *et al.* (2023) present a comprehensive study on the SPECTRUM project,

showcasing a pioneering approach to tackling societal challenges in Canada. Initiated in 2018, the SPECTRUM Partnership addresses the fragmented nature of social services, which often suffer from a lack of coordination and evaluation, leading to suboptimal outcomes and resource wastage (Enns *et al.*, 2023). This tripartite model, comprising community organizations, government, and academia, transcends traditional hierarchical frameworks, favoring a more egalitarian, knowledge-sharing approach (Enns *et al.*, 2023). By integrating diverse perspectives and expertise, SPECTRUM effectively navigates the intricacies of public policy, social services, and systems (Enns *et al.*, 2023). The partnership emphasizes community-driven research, leveraging existing data to fill knowledge gaps in social programs (Enns *et al.*, 2023). Their findings are transformed into practical policy proposals, aligning with governmental priorities and offering tangible solutions to complex social issues (Enns *et al.*, 2023). This collaborative model not only fosters holistic solutions but also ensures their relevance and effectiveness in addressing the real-world complexities of the problems at hand, demonstrating a viable path for optimizing public policy development in a collaborative, evidence-based manner (Enns *et al.*, 2023).

Lieberknecht *et al.* (2023) present a comprehensive view of the transdisciplinary climate research PT2050, a model that equally values scientific and humanistic disciplines. PT2050's success in integrating diverse epistemologies and methodologies is credited to its focus on disciplinary equity and its inclusion of community partners in co-designing research, thereby avoiding technological solutionism (Lieberknecht *et al.*, 2023). By fostering an environment where different disciplines and community stakeholders can collaborate as equals, PT2050 serves as an example of how GCs can transcend traditional academic silos to address wicked problems.

Transitioning from focusing on successful transdisciplinary projects like SPECTRUM and PT2050, it's important to address the inherent challenges of such collaborations. Merging various academic disciplines and community insights, transdisciplinary work often faces hurdles due to conflicts with entrenched discipline-based conventions, structures, and norms. Because of this, it is generally more difficult to co-create than aggregate research. This reality calls for understanding the intricate dynamics and challenges research teams encounter in interdisciplinary settings.

2.3 Teaming Concerns

Interdisciplinary research often demands significant time, is prone to disagreements, necessitates blending different knowledge systems and methods, and calls for adaptability, thorough planning, and mutual trust within the team (Piqueiras *et al.*, 2023). Piqueiras *et al.* conducted a detailed ethnographic study within a larger, federally funded, interdisciplinary scientific team, employing participant observation, semi-structured interviews, and a focus group over six months. They aimed to uncover and mitigate challenges in team science across institutional, cultural, and interpersonal levels. Their findings highlight that by understanding and addressing the three primary barriers of academic culture, institutional structures, and interpersonal dynamics, targeted team-building exercises and specialized training can be effectively employed to mitigate these concerns (Piqueiras *et al.*, 2023). The SNAP project at Boise State, in embracing these insights, aims to explore how such challenges and proposed solutions manifest within the GCs initiative, thereby contributing to a more effective model of interdisciplinary collaboration.

Bednarek *et al.* (2023) research how grand challenge research teams achieve sustained research impact through time across multiple projects. There is an ebb-and-

flow of activities and membership, which needs to be managed (Bednarek *et al.*, 2023). They acknowledge the increasing demands for impactful research on grand societal challenges and identify several barriers, including institutional constraints, knowledge translation difficulties between researchers and practitioners, and the long timescales required for impactful outcomes (Bednarek *et al.*, 2023). These challenges are compounded by the need for sustained engagement with stakeholders and the integration of diverse perspectives within research teams (Bednarek *et al.*, 2023).

2.3.1 Crossing Disciplinary Boundaries

Interdisciplinary research, while crucial for addressing complex societal challenges, faces inherent difficulties due to varying academic cultures, methodologies, and terminologies. Dalton *et al.* (2022) emphasize that effective interdisciplinary collaboration, organized around a central principle like the GCs, is not without its limitations. Researchers often find it difficult to see beyond their disciplinary confines, a hurdle evident in Boise State's GC initiative Healthy Idaho, where early observations by LaRosa indicated struggles among researchers to envision their work within the broader societal framework (LaRosa, 2023b, personal communication, September 25).

Similar issues were reported by Piqueiras *et al.* (2023), which found that team members often reverted to thinking through their disciplinary lens, leading to conflicting ideologies and tensions in knowledge integration. Differences emerged between trusting team members' expertise and trusting them as individuals, highlighting the necessity of actively creating a culture of trust (Piqueiras *et al.*, 2023). Collaborating with various organizations, communities, and governing bodies brings additional trust challenges, such as differing research goals, ethical practices, and resource availability.

Collaboration failures have been blamed on epistemic and ontological incompat-

ibilities, such as interpersonal or political problems and barriers related to language and terminology between disciplines (Dalton *et al.*, 2021). In Belgian study, Duysburgh *et al.* (2012) found these types of barriers within multidisciplinary research groups focusing on information and communication technologies. Using ethnographic methods, including surveys, workshops, observations, and interviews, Duysburgh *et al.* explored the integration of diverse academic and community members. They found that the teams struggled to understand how other members would contribute to that larger, common goal, explaining various reasons why. STEM scientists struggle to understand how social scientists can contribute to a project or see their added value (Duysburgh *et al.*, 2012). Additionally, rapid growth in team size led to increased specialization and differentiation among members, which posed a challenge to maintaining coordination and cohesion Duysburgh *et al.* (2012).

Competition between groups fostered further specialization, creating clusters within the teams and distancing the research groups from their university affiliations (Duysburgh *et al.*, 2012). Teams were structured hierarchically with junior, senior, and head levels, alongside supportive roles like secretaries. However, this structure sometimes led to a sense of exclusion among junior researchers, who had limited involvement and access to information (Duysburgh *et al.*, 2012). These factors lead to researchers not understanding the greater research agenda, which means that the result is an aggregation and not a co-creation of creative work.

In addressing interdisciplinary understanding, the perspective of critical realism, as advocated by Dalton *et al.* (2022), offers valuable insights. Critical realism, combining ontological absolutism (external structures) with epistemic relativism (the subjectivity of human understanding), provides a robust framework for understanding

the structures and mechanisms in the real world and, by extension, within interdisciplinary teams (Dalton *et al.*, 2022). This philosophical approach assists in unraveling the complexities of interdisciplinary interactions and identifying potential sources of conflict or misunderstanding among diverse team members.

Effective communication is vital for coordination, learning, research integration, and mitigating distrust perceptions. Trust, including cognitive (trust in the expertise of others) and affective trust (emotional bond among team members), is fundamental in collaborations (Sonnenwald, 2007). Critical realism may help in building both cognitive trust and affective trust by acknowledging and valuing the contributions of different disciplines. By recognizing and accommodating different epistemological standpoints, critical realism fosters a constructive working environment where differences are not seen as barriers but as enriching elements of a shared objective reality. Critical realism can be instrumental in addressing STEM scientists' skepticism toward social scientists' contributions, as Duysburgh *et al.* reported. Implementing critical realism in practice could involve structured reflection sessions where team members discuss and acknowledge their disciplinary biases and work towards a shared understanding.

Learning, both explicit and tacit, is a critical component of collaborative research, particularly in interdisciplinary settings (Sonnenwald, 2007). However, learning is often challenging and not typically included in research proposals (Sonnenwald, 2007). Duysburgh *et al.* suggest that plenary project meetings, while bridging gaps between specialties, often missed opportunities for effective collaboration. A more frequent and focused meeting approach based on common research interests was recommended (Duysburgh *et al.*, 2012).

Furthermore, critical realism's emphasis on reflexive thinking encourages team members to be aware of and question their biases and assumptions, leading to more empathetic interactions and stronger affective trust. Critical realism encourages researchers, such as engineers, to appreciate social science's qualitative, context-rich insights, complementing the quantitative, empirically focused approaches typical of STEM fields.

2.3.2 Scarcity of Time

In the GCs initiative, efficient time management and realistic goal setting are key strategies to mitigate the challenges of time scarcity identified by Piqueiras *et al.* (2023). Their study found that a constant perception of being behind and urgency affected project management and task division (Piqueiras *et al.*, 2023). Additionally, a consistent issue was the regret and guilt expressed by team members regarding their inability to dedicate sufficient time to the project. This scarcity of time also affected the follow-through on tasks, depending on each member's availability and capacity (Piqueiras *et al.*, 2023). Unrealistic timelines and conflicting responsibilities strained investigators and trainees (Piqueiras *et al.*, 2023). The research team faced challenges with project management due to a lack of dedicated coordinators and unrealistic funding expectations (Piqueiras *et al.*, 2023). This was exacerbated by funding institutions' requirements for principal investigators to propose ambitious project timelines, often beyond realistic scopes (e.g., a 10-year project within a 5-year timeframe) (Piqueiras *et al.*, 2023).

Duysburgh *et al.* (2012) also recommend strong project management to solve the difficulties inherent in interdisciplinary work (Duysburgh *et al.*, 2012). The lack of a unified software solution led to confusion, and project websites were viewed negatively

(Duysburgh *et al.*, 2012). Multiple funding sources, while providing stability, imposed greater administrative burdens, particularly on senior researchers and administrators (Duysburgh *et al.*, 2012). The GCs investments include assisting researchers in project management to reduce administrative burdens.

2.3.3 Institutional Structures

Various institutional structures, including funding agencies, universities, IRBs, and bureaucratic partners, highlight how these structures shape collaborative research (Piqueiras *et al.*, 2023).

Institutional Structures affect the attraction to research collaboration. As Okraku *et al.* (2017) emphasize, the predominance of unidisciplinary collaborations in scientific research is often a result of established organizational structures, training processes, and institutional reward systems. Such collaborations enable rapid consensus-building and efficient results production due to shared training and language (Okraku *et al.*, 2017). Nonetheless, this emphasis on unidisciplinary work often leads to its prioritization in tenure and promotion processes, potentially fostering knowledge silos (Okraku *et al.*, 2017). Lyall & Fletcher (2013) suggests that the preference for disciplinary over interdisciplinary research is often shaped by the funding frameworks of research institutions, which establish the guidelines and priorities governing the allocation of resources. Collaborative work can be marginalized or discounted within departments, especially if only one scientist is involved in a specific collaboration (Sonnenwald, 2007), leading to the creation of knowledge silos and impeding the diffusion of knowledge across disciplines (Okraku *et al.*, 2017). The GCs initiative aims to allow individuals to work in an interdisciplinary way that serves their own disciplinary work (LaRosa, 2023b, personal communication, September 25). This thesis

will not evaluate institutional incentives and disincentives to collaborating at Boise State. It is beyond the scope of this project. Understanding these institutional influences is crucial for the SNAP project, as it navigates Boise State's structures to foster effective interdisciplinary collaboration within the GCs initiative.

2.3.4 Politics and Its Influence on Research Freedom

The broader political environment can influence the pursuit of innovative solutions within academic research, such as those endeavored by the GCs initiative. Political factors often shape research agendas, especially concerning wicked problems that intersect with public policy and societal issues. In navigating these political landscapes, research initiatives may face challenges that require cautious strategy, potentially influencing the scope and direction of their inquiry.

For instance, during the planning phase of the GCs, the selection of thematic areas for research was influenced by the prevailing political climate. Originally proposed topics, some of which delved into areas of equity and justice, were reassessed considering the time's broader political and social context (LaRosa, 2023b, personal communication, September 25). Such decisions highlight the complex interplay between academic freedom and political considerations, underscoring the delicate balance research initiatives must maintain.

Furthermore, research projects that delve into areas of social and political sensitivity can encounter unique challenges. For example, certain research plans within the GCs initiative faced delays and adjustments due to their intersection with contentious issues (LaRosa, 2023b, personal communication, September 25). These incidents underscore the intricate balance required between academic exploration and political realities. Such experiences are not unique to any particular institution or state but

reflect a common challenge faced by researchers globally: navigating the delicate interface between academic inquiry and the political landscape.

2.3.5 Interpersonal Relationships & Leadership

Pre-existing collaboration histories among senior team members set implicit expectations for new members, complicating the team dynamics and contributing to feeling overwhelmed (Piqueiras *et al.*, 2023). Sonnenwald (2007) also addresses concerns about unethical conduct, intellectual espionage, and skewed funding toward collaborative research at the expense of single investigators. Duysburgh *et al.* (2012) noted that internal competition reserved team member collaboration efforts, resulting in some researchers and companies only using the initiative as a funding source. In the SNAP project, being cognizant of existing collaboration histories and their impact on team dynamics is vital to fostering a cohesive interdisciplinary research environment.

Networks of scientific collaboration facilitate the spread of knowledge and innovation throughout various disciplines and institutions (Okraku *et al.*, 2017). Disis & Slattery (2010) describe the connective thinking process through which an individual's innovative idea moves through the team. After being fully evaluated, the idea becomes a sum of the team's input (Disis & Slattery, 2010). Moody (2004) cites theorists who argue that an individual's ideas are a function of their position in a social setting, which is deeply structured by interaction patterns. The shape of the idea can be linked to the structure of a network, and in small groups, ideas and their movement depend on the authority structure (Moody, 2004). Leadership, therefore, plays a pivotal role in the success of these teams, with transformational leaders being essential for motivating, moderating, and mentoring diverse groups (Disis & Slattery, 2010).

Glied *et al.* (2007) describe sustainable leadership characteristics of center directors as charismatic and capable of negotiating with administrators, department chairs, and center members. A transformational leader is dedicated to mentoring and sacrifices self-interests to align projects and resources with the team's goals and priorities (Disis & Slattery, 2010). Bland *et al.* (2005) describe research leaders as being regarded highly as a scholar and a sponsor, mentors, and peer models. When selecting interdisciplinary leaders, DRED considered faculty researchers seasoned in their careers, capable of "floating all boats within a thematic area" (LaRosa, 2023b, personal communication, September 25).

Interdisciplinary leaders face challenges in publication and dissemination, including finding appropriate forums for interdisciplinary results, consensus on authorship, and different disciplinary expectations (Sonnenwald, 2007). LaRosa gives an example from her personal experience assisting research collaboration.

> "In some disciplines, writing papers has less value. They disseminate their work through conferences. That is all they need to get a promotion and tenure. The faculty in a different discipline might need to publish to get a promotion and tenure. This leaves one person stuck writing" (LaRosa, 2023b, personal communication, September 25).

Addressing these issues at the onset of collaboration is critical for the success and recognition of research outcomes. Collaborations may face challenges due to varying informal traditions and norms among disciplines, especially regarding intellectual property sharing. For instance, experimental biologists often patent their ideas, while mathematicians are more open (Sonnenwald, 2007). Model agreements provided by funding agencies can streamline the development of a shared understanding of IP and

other legal issues (Sonnenwald, 2007). Further research may consider investigating the personality characteristics of interdisciplinary team leaders to customize leadership training and extend the specific resources to fill the leader's gaps.

2.4 New and Expanded Opportunities Across Campus

With the selection of seasoned faculty as leaders, there is a concern that the GCs investments may not benefit campus researchers. LaRosa articulated this by saying, "Any time an initiative holds resources for a specific venture, faculty may think that it is intended to empower the powerful and not extend to faculty as a whole" (2023b, personal communication, September 25,). Additionally, the blueprint for Boise State's success calls for the promotion of a fair, equitable, and accessible environment for all members of campus to make a difference (Research and Economic Development, 2024). Therefore, the SNAP project aims to assess if the GCs initiative effectively broadens engagement opportunities across campus, ensuring that all interested faculty members can participate and contribute.

Disis & Slattery (2010) point out that loud and powerful researchers tend to receive resources. This could undermine the goals of the GCs investments as those with the most power perhaps could have found external resources where those without prestige continue to struggle to collaborate. Sonnenwald (2007, p. 8) points out that collaborations "become powerful lobbying groups, influencing research policy and funding decisions in their favor." This inequality underscores the importance of ensuring systemic biases in allocating resources and opportunities do not undermine Boise State's GCs initiative. In chapter 5 of this thesis, I aim to examine whether

individuals selected to participate in the GCs teams are positioned so that they can effectively promote new and expanded opportunities across campus.

2.5 Evaluating Scientific Collaboration

Team science collaborations are embedded in a dynamic system encompassing social relationships, cultural contexts, and institutional power structures. This web influences and shapes the nature and outcomes of scientific teamwork. It is essential to study this system to ensure the GCs initiative reaches its outcome goals and to tackle Idaho's Grand Challenges.

Given these considerations, a spectrum of methodologies has been employed to study collaboration. Sonnenwald (2007) highlights approaches like bibliometrics, interviews, observations, experiments, surveys, simulations, self-reflection, social network analysis, and document analysis. Each method offers unique insights, shedding light on different aspects of collaboration, from quantifiable data to nuanced interpersonal dynamics. Leite & Pinho (2017, p. 6) further delineate the study of research networks into three distinct levels: "macro," focusing on national and international contexts; "meso," addressing organizational or institutional level; and "micro," exploring interactions within specific research groups.

In this thesis, my approach is multifaceted, utilizing several methods and analytical levels to comprehensively understand collaboration at Boise State. I conduct thematic analysis of semi-structured interviews and focus groups of various Boise State research faculty. I leverage SNA to capture meso- and micro-level network structural patterns. I apply SNA to historical grant proposal networks and describe and compare research team networks. In other cases, the analysis is explicitly generative, positing a micro-level behavioral model that produces a population-level network

structure, such as clustering disciplines. This work will aid in the customization of the GCs initiative's research support plan. It will also contribute to the growing literature on team science and specifically research teams addressing society's grand challenges.

The upcoming chapter, Chapter 3: VAMPIRE, will examine the institutional, cultural, and interpersonal factors influencing collaboration at Boise State. This chapter aims to delve deeper into the collaboration dynamics within Boise State using semi-structured interviews and focus group data. I explore the culture of collaboration before introducing the GCs interventions.

CHAPTER 3:

VAMPIRE

3.1 Vicken And Many Persons Interview Research Enterprise

In the previous chapter, I discussed the critical role of collaboration in addressing complex scientific challenges and advancing broader societal goals, such as sustainable development and cultural integration. Collaboration, by bringing together diverse expertise and perspectives, not only extends the scope of research projects but also enhances innovation, scientific reliability, and the probability of success (Sonnenwald, 2007; Disis & Slattery, 2010). The importance of multidisciplinary teams in fostering dynamic, connective thinking and achieving radical innovations was emphasized, highlighting the necessity of such collaborative efforts for tackling the United Nations' Sustainable Development Goals (SDGs) and other wicked problems (Rittel & Webber, 1973).

I also explored the distinction between intradisciplinary and interdisciplinary collaborations, noting that while the former focuses on generating knowledge within a specific domain, the latter is crucial for addressing broad, complex issues that transcend single disciplines (Sonnenwald, 2007; Dalton *et al.*, 2021). The value of interdisciplinary research has been further underscored by the support from federal

agencies and the strategic emphasis on team-based approaches at Boise State, as discussed by Jana LaRosa (2023b, personal communication, September 25). This chapter continues to explore the mechanisms and impacts of scientific collaboration in greater detail. In phase 1, VAMPIRE asks, "In what ways do faculty at Boise State conceptualize collaboration beyond traditional metrics such as proposal applications and publications?" and "What diverse forms of collaboration are prevalent among Boise State faculty, and how do these collaborations manifest in academic settings?"

3.2 Methods

3.2.1 Thematic Analysis

Thematic analysis is a complementary technique that sorts concepts and categories (Jonsen & Jehn, 2009). It is often used to offset research biases in data interpretation, integrating qualitative and quantitative methods (Jonsen & Jehn, 2009). Coding levels are a data reduction process (Jonsen & Jehn, 2009). NVIVO facilitates data reduction and coding procedures (Jonsen & Jehn, 2009). Concepts are at a higher level (Jonsen & Jehn, 2009). Categories are aggregated into fewer second-order concepts (Jonsen & Jehn, 2009). Categories stem from the analyst's insights (Jonsen & Jehn, 2009).

Answering the need for a general understanding of interdisciplinary research and how it can be successfully integrated and sustained in academic centers and universities, Glied *et al.* (2007) employ thematic analysis on extensive notes taken from directors of interdisciplinary research centers focus groups working to characterize successful and challenges factors facing their centers and university are facing (Glied *et al.*, 2007). The primary challenges identified include fiscal sustainability, faculty

recruitment and retention, and leadership sustainability (Glied *et al.*, 2007). Fiscal sustainability involves continuous external funding, managing indirect costs, and securing resources such as space and administrative support (Glied *et al.*, 2007). Faculty challenges relate to adapting to interdisciplinary environments, satisfying departmental criteria, varying expectations across disciplines, and providing incentives for involvement (Glied *et al.*, 2007). Leadership sustainability encompasses the administrative burden and maintaining continuity despite leadership changes (Glied *et al.*, 2007).

Piqueiras *et al.* (2023) work to uncover and mitigate challenges in team science by employing participant observation, semi-structured interviews, and a focus group method, studying an interdisciplinary team for over six months. They argue that thematic analysis and ethnography can effectively identify and address practical tensions and contextual factors that hinder scientific collaboration (Piqueiras *et al.*, 2023). After intensive data collection, the authors used code derived from their literature review and compared the findings across the data sources for validation (Piqueiras *et al.*, 2023). The main thematic areas include academic culture, institutional structures, and interpersonal dynamics with disciplinary boundaries, scarcity of time, and trust and accountability nested subthemes in each main theme (Piqueiras *et al.*, 2023).

To assist SNAP in answering what collaboration looks like at Boise State prior to the GCs investments, I seek to describe pre-GCs investment in collaboration and identify barriers to collaborative science in the Bosie State research culture. Vicken And Many Persons Interview Research Enterprise (VAMPIRE) is a research branch of SNAP tasked with conducting and analyzing informal Boise State faculty interviews about collaboration. VAMPIRE asks, "How do faculty define collaboration (thinking

beyond proposal application and publication)?" and "What other ways do faculty collaborate?" Using focus groups and semi-structured interviews, faculty responses are analyzed by coded themes. The results of this research are reported in chapter one of this thesis. Using thematic analysis, I aim to set the groundwork for future longitudinal analysis by examining Boise State faculty's current attitudes towards and activities doing collaborative creative work.

Employing thematic analysis, I probe the structural and cultural facets of the Boise State research community. My methodology, integrating focus groups and semi-structured interviews, seeks to build a comprehensive, multi-faceted dataset, enriching my analysis of faculty collaboration dynamics at Boise State. The amalgamation of SNA and thematic analysis serves to visualize collaboration trends and identify meaningful research teams marrying quantitative network descriptions with qualitative contextual insights.

3.2.2 Data Collection

Focus Groups

In 2020, the initial data collection phase commenced with faculty focus groups. These groups, formed through self-selection via a "Funding Blast" emailer, were tasked with discussing research communication and the inherent challenges of collaborative endeavors (LaRosa, 2023b, personal communication, September 25). Facilitators Jana LaRosa and Nancy Glenn led these discussions, which were later systematically categorized into nine distinct themes using NVIVO's auto-coding feature (LaRosa, 2023b, personal communication, September 25). Twenty-five emergent themes ranged from the identity of collaborators ("faculty", "students", "relationships") to the modalities and motivations of collaboration ("skills," "opportunities,"

"funding", "professional development"), the frequency of interaction ("team communication"), and the logistical and interpersonal challenges encountered ("Connecting with Others," "Envisioning Collaboration Opportunities," "Funding," and "Time"). I then used the "Roll-up" auto-code process, which uses the emergent themes to reduce the thematic areas further. This resulted in the five themes: "Communication," "Culture," "Disciplinary," "Institution," and "Teaming Advice." Figure 3.2 is the focus group hierarchy chart showing codes and sizes of the boxes by the number of coding references. I ensured that each response was coded into only one theme.

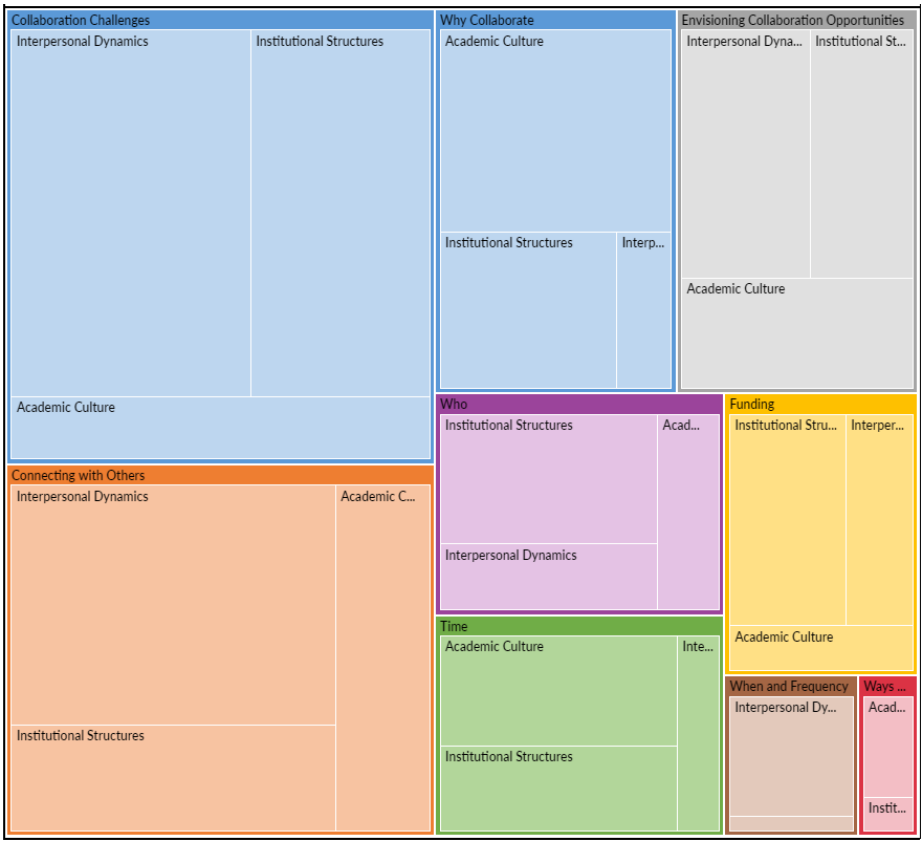

Figure 3.1: The focus group hierarchy chart showing a code comparison by number of coding references

These thematic insights are then aligned with the primary codes derived from

Piqueiras *et al.* (2023): Academic Culture, Institutional Structures, and Interpersonal Dynamics, thus offering a refined lens through which to view the faculty's collaborative experiences.

Semi-Structured Interview

Semi-structured interviews were conducted via Zoom between November 2022 and January 2023. The SNAP team meticulously developed the interview script, which spanned various collaborative aspects, from subjective feelings of closeness to collaborators to structural barriers and enablers. Five interviewees were selected from the Biology, Psychology, and Anthropology departments due to my existing acquaintanceships. These interviews were transcribed and manually analyzed using NVIVO, following a similar thematic classification as the focus groups, thus ensuring a cohesive and comprehensive analysis across both data collection methods. Figure 3.2 is a hierarchy chart for the semi-structured interviews showing a code comparison by the number of coding references.

3.3 Analysis

3.3.1 Academic Culture

Academic culture, with its complex web of entrenched norms and subtle resistance to change, plays a critical role in shaping the landscape of collaborative research (Piqueiras *et al.*, 2023). Within this culture, various dimensions emerge, reflecting the multifaceted nature of academic work and the challenges it presents. From the recognition of collaborative achievements and the dynamics of faculty support to the pursuit of novel approaches and the omnipresent pressure of time constraints, academic culture is a tapestry of interactions, expectations, and practices. This section

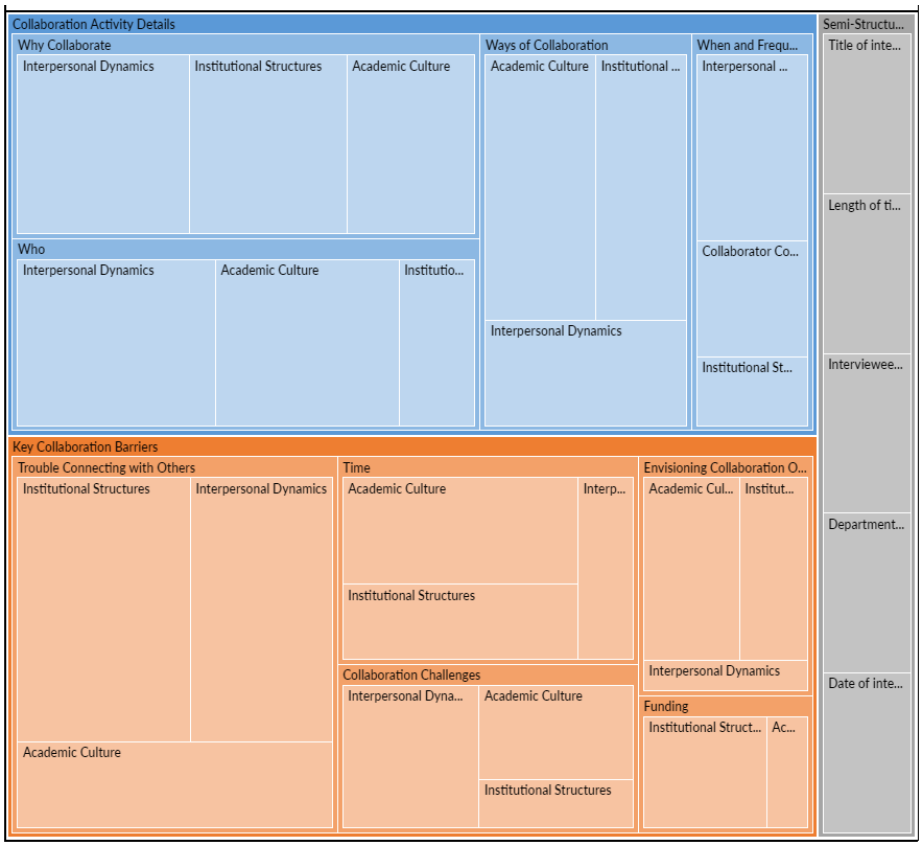

Figure 3.2: The semi-structured interviews hierarchy chart compares codes by the number of coding references.

delves into these aspects, untangling how academic culture influences, constrains, and catalyzes the collaborative spirit in research endeavors.

Achievements and Acknowledgements

The concept of collaboration in academia, particularly through co-authorship on manuscripts or joint principal investigator roles on grants, is a significant marker of completed creative work and is deeply entrenched in academic culture. This is exemplified in the observation, "To me, it means to be a co-author on a manuscript or a Co-PI in a grant," highlighting the formal recognition of shared effort and responsibility in research endeavors. However, a nuanced challenge emerges within this

context: the potential overshadowing of collaborative efforts by individual achievements. Faculty narratives, such as "not once did anything ever come from that in terms of publication" and "the outcome is not always as beneficial as we hope," reveal a cultural tension where the value of collaborative endeavors may be undermined if they do not culminate in conventional academic outputs like publications. This tendency to prioritize individual accomplishments over collective efforts poses a critical challenge to collaborative research ethos.

The vulnerability of junior faculty in collaborative projects is particularly noteworthy. They are often more open to engaging in collaborative projects driven by energy and the need to develop diverse research portfolios. However, they face heightened risks, as the sentiment illustrates, "contracts don't reflect a jr. faculty doing robust research." This statement underscores institutional barriers that can hinder effective collaboration, pointing to a gap in the support structures for early-career researchers. Such barriers impede collaboration and affect the career trajectory and development of junior faculty. In contrast, senior faculty and more experienced researchers are pivotal in shaping the collaborative landscape. As Allison Simler-Williamson's experiences suggest, mentorship from seasoned academics provides invaluable guidance and support to less experienced colleagues, fostering an environment of professional growth and development. This mentorship is a cornerstone of academic culture, facilitating knowledge transfer and nurturing research skills among emerging scholars.

Faculty Support and Departmental Dynamics

The role of departmental leadership and culture in fostering or impeding collaboration emerges as a central theme in academic settings. Faculty anecdotes reveal how shifts in departmental chairmanship can significantly alter the research environment.

For instance, one faculty member noted the profound impact of leadership changes on the culture of support and encouragement for research, highlighting the pivotal role of departmental heads in cultivating a conducive atmosphere for collaboration. This underscores the intricate balance between maintaining individual research autonomy and embracing collaborative efforts. Statements like "In the department of psychological science, research, and creative activity are largely autonomous" contrast starkly with reflections on the value of collaborative work, displaying a prevalent culture of individual research efforts in some academic settings.

This theme resonates deeply when considering opportunities for collaboration, particularly in departments where solo endeavors are the norm. It points to the necessity of balancing individual research autonomy with collaborative initiatives. The significance of institutional support in facilitating collaboration is underscored by remarks such as "The department has been supportive with all collaboration" and "They are vital in helping me create space to meet deadlines." Such comments illustrate how variations in leadership and departmental culture can profoundly influence the extent and effectiveness of collaborative efforts among faculty. Departmental policies and practices, as outlined by Okraku *et al.* (2017), play a formative role in shaping the scientific community's landscape, encompassing aspects like federal programs, funding opportunities, hiring practices, resource allocation, and graduate training.

Interpersonal dynamics within collaborations also reveal interesting patterns. As noted by all interviewees, faculty engage in collaborations not only within their departments but also with external professionals and community partners. These relationships, characterized by mutual respect and shared research interests, vary in closeness and formality. However, challenges arise in interdisciplinary collaborations,

particularly in communication across different disciplines. Faculty express concerns about the "Lack of exposure to other disciplines" and the difficulties posed by "No shared language." These issues highlight the necessity for effective communication strategies, such as the ability to "code switch in these environments" and "write for your audience" to bridge disciplinary divides. The need for adaptable communication styles is thus emphasized as a crucial component for successful collaborative work, as it facilitates the integration of diverse perspectives and the smooth flow of ideas.

Embracing Novel Approaches

The process of venturing into new intellectual territories and the challenges of finding common ground across disciplines is a recurring theme in the pursuit of collaboration opportunities. Faculty members describe this journey with statements like, "You are always moving into new intellectual areas gradually," capturing the essence of academic exploration and the gradual shift toward interdisciplinary work. However, this endeavor is not without its challenges, as indicated by the observation, "I do not see many opportunities where the overlap exists." Such comments reflect a keen awareness of the difficulties in identifying and developing interdisciplinary collaborations, highlighting a need for more structured opportunities to foster these connections.

Beyond the box of traditional research, the integration of research with teaching and public engagement emerges as a significant collaborative avenue. Faculty members advocate for a broader conception of academic productivity, as evidenced by sentiments like "Don't treat research as a single theme - integrate more with teaching" and "Broaden what we think of as research, plus public outreach and engagement." These perspectives underscore the potential for collaborative efforts that

extend beyond conventional research boundaries, encompassing teaching and community involvement. This approach is not merely a suggestion but a call to action, challenging the status quo of academic work.

Integrating teaching, research, and service activities is further illuminated by references such as "Collaborate with our classes and artwork" and "Integration of teaching and service is important." These insights reveal a holistic perspective on faculty roles, where the silos of teaching, research, and service are not only interconnected but also mutually reinforcing. This integrative approach is essential in cultivating a more comprehensive and multi-dimensional academic culture that values and promotes a wide range of scholarly activities. It speaks to a dynamic understanding of academia, where the traditional boundaries of research, teaching, and service are reimagined to create a more fluid and interconnected scholarly practice.

Limited Time

In academic culture, the perception of time and its constraints plays a pivotal role in shaping faculty experiences and priorities. This is vividly reflected in numerous observations from faculty, such as "Time is the biggest challenge" and "Don't have enough workload to focus on research." These comments underscore a pervasive sentiment of time scarcity, which goes beyond mere institutional structures to the very heart of academic culture. It points to an ingrained belief within the academic community that there is always a deficit of time, fueling a sense of constant urgency. This cultural perspective on time highlights the ongoing struggle of faculty members to juggle their diverse roles in teaching, research, and administrative duties. Rather than being solely a product of institutional demands, this tension is deeply embedded in the academic mindset, shaping how faculty perceive and manage their time.

Conclusion

In summary, academic culture is a potent force that shapes the contours of collaborative research in profound ways. It is manifested in the quest for achievements and acknowledgments, where the balance between individual and collective successes is delicately negotiated. Faculty support and departmental dynamics further color this landscape, illustrating how leadership styles and departmental ethos can significantly impact collaborative endeavors. Embracing novel research, teaching, and public engagement approaches reflects a growing trend toward interdisciplinary and integrative practices, challenging the traditional confines of academic roles. Meanwhile, the pervasive issue of limited time underlines a cultural norm of constant urgency and the struggle to juggle diverse academic responsibilities.

The next section, "Institutional Structures," highlights that these cultural themes are inextricably linked to the broader institutional context. Here, I will explore how the structures and policies at Boise State further influence and shape the practice of collaborative research.

3.3.2 Institutional Structures

This section explores the multifaceted role these structures play in facilitating or hindering the collaborative process within academic settings. I delve into the crucial aspects of resources, infrastructures, and policies that shape the terrain of academic collaboration. Emphasis is placed on the pivotal role of administrators, as highlighted by Allison Simler-Williamson, in providing essential support and navigating the complex bureaucracy inherent in academic departments. I will examine the infrastructure support necessary for fostering a collaborative environment, the intricate balance of workload policies that influence faculty's ability to engage in research, the nuanced

mechanisms of funding structures that drive collaborative initiatives, and the vital role of integrating students into the collaborative framework. Each of these components reveals a different facet of how institutional constructs can either support or constrain the collaborative efforts of faculty and students in academia.

Infrastructure Support

Faculty voices echo the sentiment that institutions must develop a deeper understanding and robust support for interdisciplinary research. Phrases such as "University needs to understand what it means for faculty to do interdisciplinary research" and "Make sure the university supports interdisciplinary work" underline the necessity for institutional awareness and explicit support. This perspective points to a gap in current institutional structures – a gap that, if bridged, could significantly enhance the efficacy and productivity of collaborative research endeavors. The emphasis on interdisciplinary work also reveals a broader institutional challenge: adapting and evolving to accommodate and nurture diverse research methodologies and partnerships.

The necessity for physical and strategic infrastructures that promote collaborative research is repeatedly emphasized in faculty discussions. Statements like "creating opportunity and space for the human connection" and calls for a "central repository for seminars" highlight a significant institutional need. These references underscore the critical importance of designing physical and virtual spaces that encourage interaction, idea exchange, and the nurturing of collaborative relationships among faculty members. Such infrastructures are more than mere conveniences; they are essential frameworks supporting collaborative work's complex dynamics.

An additional layer of complexity emerges when considering faculty responsibil-

ities and integrating new initiatives. Comments like "It feels like an extra layer of work to do on top of my work" reflect the tension between existing duties and additional collaborative projects. This sentiment illustrates faculty's ongoing struggle to balance their workload, often exacerbated by institutional expectations. Moreover, the discussion on the need for tenure and promotion policy changes to honor diverse skills demonstrates the structural barriers to interdisciplinary research. These policies often dictate faculty priorities and can inadvertently hinder the pursuit of innovative, collaborative projects.

Incentives, both monetary and in terms of recognition, are cited as crucial motivators for collaborative efforts. Faculty reference the importance of tangible rewards, such as being included in grants or receiving time allocations, to justify their engagement in collaborative projects. These incentives are essential elements that validate and encourage the investment of time and effort in collaborative work. They also serve as recognition of the value and impact of such efforts within the academic community.

Workload Policy

The intersection of faculty workload policies and research collaboration forms a complex and often challenging aspect of institutional structures. Faculty narratives, laden with references like "Conflicted with existing workload policy" and "No way to reimagine the contract - workload," lay bare the direct impact of university workload guidelines on the allocation of time for research and collaborative efforts. These policies, deeply embedded within institutional frameworks, often dictate the distribution of faculty time, significantly influencing their capacity to engage in research activities.

The conundrum of effectively managing and prioritizing time amidst diverse responsibilities is palpably felt in the academic community. Statements such as "figuring

out what fits, and it adds one more thing to the plate" and the evocative "Hard rule of 3:3 in the COED – teaching is getting cranked up!" reflect the intricate juggling act faculty must perform. The "3:3" rule, a stringent requirement of teaching three classes per semester, epitomizes the substantial teaching responsibilities that can overshadow research endeavors. This scenario underscores a key challenge: balancing the demanding roles of teaching, administration, and research.

The impact of workload allocation on faculty's ability to immerse themselves in innovative research and collaboration cannot be overstated. Phrases such as "We don't account for the time to do team science" and "Need free time to be innovative and work through a problem..." highlight an institutional blind spot regarding the time necessary for collaborative and creative research pursuits. These statements call for a reevaluation of workload policies to accommodate the time-intensive nature of collaborative research. The essential question is whether institutions can adapt their workload structures to foster an environment where research and collaboration are not just encouraged but practically feasible.

The narrative also brings to light the need for structural support mechanisms to facilitate dedicated research time. Suggestions like "Could there be mini-sabbaticals to create time for faculty?" and "Clear guidelines about time off and course buyouts that apply across campus" propose innovative solutions to the time dilemma. These ideas signify the need for institutional initiatives such as sabbaticals or course buyouts, which can provide faculty with the much-needed respite to focus on research. Such measures are not merely conveniences but essential components of a supportive academic environment that recognizes and values the importance of research and collaboration.

Funding Structures

In the landscape of academic research, funding mechanisms like the "Cobrea grant" and the "One-Health initiative" serve as key drivers for interdisciplinary collaboration. These initiatives, often requiring collaborative efforts across various disciplines, illustrate how funding structures can catalyze interdisciplinary research. However, securing funding in such contexts is fraught with challenges, as encapsulated in the struggle of "Finding funding and collaborators who get it" within "small and interdisciplinary spaces." This predicament underscores a critical gap in traditional funding models, which may not adequately accommodate the nuanced needs of interdisciplinary projects. The struggle to find appropriate funding sources and collaborators who appreciate the interdisciplinary nature of the work highlights an urgent need for more adaptable and inclusive funding mechanisms that can embrace the complexity of interdisciplinary research.

The control exerted by university administrators over funding resources is a pivotal theme. Statements like "The administrators also hold the purse" and "They hold the keys to that kind of thing" underscore the significant influence of administrative policies and decisions on research funding. This theme highlights the often underappreciated role of administrative structures in shaping the research agenda, directing the flow of funds, and influencing the course of academic inquiry.

Seed grants emerge as a vital component in the funding landscape, serving as crucial initial support for collaborative and experimental research projects. References to "Scaling opportunities to collaborate - seed grants" underscore the role of these grants in laying the groundwork for more extensive research endeavors. Such funding opportunities are essential, especially for interdisciplinary projects that might

not fit neatly into established funding categories. The need for financial structures that support experimental and interdisciplinary research is further echoed in statements like "How to fund faculty research that is mindful of engaging students in the classroom and have cross-disciplinary conversations." These remarks reflect a call for more flexible funding models that can nurture innovative research approaches. The repeated emphasis on the importance of seed grants and funding for pilot studies, as seen in "Under resources - need small pots of money to make space for thought" and "Investment in pilot studies - to develop a track record," highlights the critical role of initial, modest financial support in catalyzing larger, more comprehensive research projects.

Student Collaborators

An essential yet complex facet of academic collaboration is the active involvement of students, particularly undergraduates, in research projects. This dimension of collaboration, as exemplified by the experiences of Cindy McCrea and Matthew Genuchi, underscores the pivotal role of mentorship in enriching students' educational journey. These collaborations offer students invaluable hands-on experience in research, contributing significantly to their learning and professional development.

The mentorship of undergraduates in research projects extends beyond conventional teaching paradigms, offering a dynamic and immersive learning experience. Such mentor-student collaborations serve a dual purpose: they provide students with critical research skills and exposure while simultaneously enriching the research capacity and innovation within the academic community. This interaction is a testament to the symbiotic relationship between teaching and research in academia, where each enriches the other.

Despite the apparent benefits, incorporating students into research collaborations is not without its challenges. Statements like "I want to recruit students for a longer period like graduate students." and references to "graduate student access/barriers/silos" underscore the structural difficulties faced in this endeavor. Training and supervising student researchers often requires significant time and resources, and retaining these students through the completion of projects can be a formidable task. These challenges highlight a broader institutional issue: the need for more streamlined and supportive mechanisms to facilitate the involvement of students in research.

The barriers to effective student integration in research often manifest as departmental silos, restrictive academic policies, and limited resources. These structural obstacles can impede the fluid movement and collaboration of faculty and students across various disciplines. Overcoming these barriers requires a concerted effort to create more flexible and accommodating institutional structures. This includes rethinking departmental boundaries, revising policies to facilitate cross-disciplinary student engagement, and allocating resources to support student involvement in research.

Conclusion

In conclusion, "Institutional Structures" reveals a landscape where collaboration is deeply intertwined with the frameworks and policies of academic institutions. The narratives from faculty members underscore the need for supportive infrastructures that encourage interdisciplinary work, flexible workload policies that accommodate research endeavors, funding mechanisms that cater to diverse and innovative projects, and the seamless integration of students into research collaborations. These structural elements are not just facilitative backdrops but active players in shaping the success

and dynamics of collaborative research. The insights gained set the stage for my next focus: "Interpersonal Dynamics." This final primary theme will delve into the human element of collaboration, exploring how personal relationships, communication styles, and individual motivations influence and are influenced by the collaborative process. As I transition to this theme, I carry forward the understanding that academic culture and institutional structures provide the frame upon which interpersonal interactions in academic collaboration are experienced.

3.3.3 Interpersonal Dynamics

Grounded in the experiences and insights of faculty members like Allison Simler-Williamson, Cindy McCrea, and Juliette Tinker, my analysis delves into the nuances of trust, respect, role clarity, mutual interests, and the balancing act of managing time demands. These dynamics paint a vivid picture of the interpersonal landscape in academic collaborations, highlighting the importance of understanding and navigating these relationships skillfully. From the initial stages of forming a collaboration based on shared interests and respect to the ongoing management of roles and expectations, these dynamics shape the course and outcome of academic partnerships. The diversity of communication styles, the evolution of relationships over time, and the challenges of aligning individual and collective goals are all integral to understanding the interpersonal fabric of academic collaboration.

Trust and Respect

Trust and mutual respect shape collaborative relationships within academia. The process of selecting collaborators is often deliberate and strategic, guided by shared research interests and a recognition of excellence in specific areas. This is reflected in the experiences of Cindy McCrea and Shelly Volsche, who underscore the im-

portance of aligning with colleagues and students who possess exceptional skills or knowledge that complement their research endeavors. This selective approach aims to forge productive and synergistic teams, emphasizing the significance of intellectual compatibility and expertise in the collaborative process.

However, establishing and maintaining trust and reliability in these relationships are not without challenges. Statements such as "you have to trust that the person is going to do what they say they are going to do" highlight the inherent uncertainty and risk in collaborative ventures. The ability to rely on a collaborator's commitment and follow-through becomes a critical factor in determining the success and viability of joint projects. Concerns about integrating collaboration within one's research program further compound these challenges, pointing to the delicate balance of trust needed to navigate these partnerships.

The emphasis on trust is complemented by the necessity of collegiality and respect in successful collaborations. The sentiment "If they have the right expertise but are awful as a person, then I won't try to collaborate with them" encapsulates the importance of respectful and professional interpersonal interactions. This underscores that expertise alone is insufficient; the quality of interpersonal dynamics plays a crucial role in the sustainability of collaborations.

Collaborative relationships, as they unfold over time, often exhibit a dynamic evolution. Allison Simler-Williamson's description of her collaborative journey, transitioning from mentorship to more balanced partnerships, exemplifies the fluid nature of these relationships. This evolution is reflective of the developmental trajectory in academic careers, where roles and contributions adapt as projects progress and individuals gain experience and insight.

The essence of collaboration in academia is also characterized by a blend of professional courtesy and reciprocal benefit. Juliette Tinker's interactions with collaborators like Mark McGuire and Rich Beard illustrate a dynamic where professional respect is intertwined with mutual benefit. These relationships are anchored in shared interests and expertise, often culminating in co-authorship on papers and joint grant applications. The notion of reciprocity is central to these dynamics, as evidenced in the exchange of resources, expertise, and recognition, enriching the collaborative experience. Tinker's collaboration with the University of Idaho's dairy farm is a prime example, where access to specialized resources and expertise was pivotal. Such inter-institutional collaborations underscore the necessity of diverse skills and resources for advancing research, emphasizing the collective strength derived from varied expertise. Interpersonal dynamics in academic collaborations are not limited to active research roles but also encompass supportive functions. Tinker's reference to Denny Stevens, primarily involved in providing letters of support, illuminates a collaborative role centered around professional endorsement rather than direct research engagement. These supportive roles are integral to the academic ecosystem, where peer validation can significantly influence the trajectory of research initiatives and grant applications.

Role Clarity, Expectations, and Autonomy

The interplay of role clarity, expectations, and autonomy emerges as a pivotal theme in interpersonal dynamics. The diversity in modes and frequency of communication among collaborators is a key aspect of academic collaborations. The experiences of Tinker and Genuchi illustrate a spectrum of communication styles, ranging from frequent emails and phone calls to more sporadic face-to-face interactions at conferences. Such variations reflect the flexibility inherent in academic partnerships,

where communication strategies are often tailored to suit the project's needs and the geographical distances between collaborators. This flexibility in communication is crucial in maintaining the fluidity and continuity of collaborative work, allowing for timely exchanges of ideas and feedback despite physical separations.

Academic collaborations manifest in formal and informal arrangements, each with distinct dynamics and implications. As seen in mentor-mentee relationships exemplified by Cindy McCrea, formal collaborations are characterized by well-defined roles and responsibilities. These structured interactions are essential for clarity and efficiency, particularly in guiding and nurturing the development of students in research settings. On the other hand, informal collaborations, such as the collegial interactions described by Allison Simler-Williamson, involve less structured engagements like tracking each other's work and exchanging feedback. These informal exchanges, while less regimented, play a vital role in creating a supportive and intellectually stimulating environment. Formal and informal collaborations contribute significantly to the richness and diversity of academic research culture, offering varying degrees of structure and flexibility.

A recurring challenge in academic collaborations is balancing individual autonomy with collective efforts. This balance is often fraught with complexities, as illustrated in references discussing work distribution and setting expectations. The delicate interplay between maintaining independence in research pursuits and engaging in cooperative efforts is a nuanced aspect of academic collaborations. Conflicts may arise from unclear roles and expectations, potentially leading to inefficiencies and strained relationships. To navigate this landscape, collaborators must establish clear communication channels, agree upon roles, and set realistic expectations from the

outset.

The essence of collaboration in academia often lies in the joint execution of research activities. Statements like "developing research protocols, collecting data, analyzing data, and writing that up" and "participating in all components of the research process" highlight the collaborative nature of the research journey. In these shared endeavors, individuals bring their unique expertise and perspectives, collaborating across various project stages – from conceptualization to dissemination. This theme is integral to academic culture, underscoring the collective effort and interdisciplinary approach that characterize much of academic research. The involvement of diverse talents and skills in these activities enriches the research output and fosters a sense of shared purpose and achievement among collaborators.

Mutual Interests

The genesis of many academic collaborations often lies in the convergence of shared research interests and goals. Juliette Tinker's collaboration with Mark McGuire is a case in point, where mutual interests in dairy research and the availability of unique resources at the University of Idaho served as the foundation for their partnership. These shared interests go beyond mere professional convenience; they are pivotal in advancing specialized research areas, especially where specific expertise or resources are scarce. Such collaborations not only fulfill immediate research needs but also contribute significantly to the broader field of study by pooling together specialized skills and resources.

The selection of collaborators often hinges on the unique skills and expertise they bring to the table, complementing those of the lead researcher. The focus group discussions highlight the strategic composition of research teams, emphasizing the value

of diverse skill sets. Statements about the need for individuals with methodological knowledge or different skills illustrate the importance of creating multidisciplinary teams. As Allison Simler-Williamson notes, such collaborations are often "greater than the sum of the parts," signifying the enhanced value derived from integrating varied perspectives and knowledge bases. This diversity not only broadens the scope of research possibilities but also deepens the intellectual richness of the project, enabling a more comprehensive exploration of research questions.

Time Demands

The inherent nature of collaborative work often entails more significant time investments compared to solitary endeavors. Faculty reflections, such as "Time - group work takes more time" and "Just adding another meeting to our schedule is just daunting," underscore this reality. Such statements highlight the additional time and effort required for group coordination, discussions, and consensus-building, which are integral to collaborative projects but can also intensify the workload. This aspect is crucial in understanding the interpersonal dynamics of academic collaborations, where the efficiency and effectiveness of teamwork hinge on the ability to manage these increased time demands effectively.

The juxtaposition of individual autonomy in research with the collective responsibilities of teamwork presents a unique challenge in collaborative environments. Comments like "There is beauty to more independent work, which is that you have your own timelines" encapsulate the freedom and flexibility often associated with solo research endeavors. However, this autonomy can be at odds with the structured timelines and shared accountability that characterize team projects. This tension reflects a significant aspect of interpersonal dynamics within academic collaborations, where

individuals must negotiate their independent work preferences with the demands and expectations of the group.

The time demands theme emphasizes the importance of understanding that time constraints and external pressures vary among collaborators. Statements such as "Understanding what other faculty pressures are in different programs" and "People shouldn't feel guilty about taking time to meet others" highlight the need for empathy and consideration toward colleagues' schedules and commitments. This respect for each other's time and workload is a pivotal aspect of interpersonal dynamics in collaborative work. It involves recognizing and accommodating the diverse responsibilities and constraints that each team member brings to the table, ensuring a collaborative atmosphere that is both productive and respectful of individual circumstances.

3.4 Conclusion

In concluding my analysis of academic culture, institutional structures, and interpersonal dynamics, I reflect on how these elements intertwine to shape the landscape of academic collaboration. My exploration of these themes has revealed a complex interplay between cultural norms, structural supports, and the intricacies of human interaction within the academic realm.

The academic culture, emphasizing achievements and faculty support, sets the stage for collaboration, often dictating its pace and direction. Institutional structures, including the pivotal role of infrastructure support, funding, and policies on workload and student involvement, either bolster or hinder collaborative efforts. These structures often serve as the framework within which collaborations must operate, setting the boundaries and providing the necessary resources.

Meanwhile, interpersonal dynamics, characterized by varying degrees of trust, re-

spect, role clarity, and mutual interests, are the lifeblood of collaborative endeavors. My discussions with faculty members like Allison Simler-Williamson, Cindy McCrea, and Juliette Tinker have illuminated the subtleties of these relationships. These dynamics are not merely supporting elements but are crucial in determining the success and longevity of collaborations. As I move from this analytical exploration to the discussion section of my thesis, I aim to delve deeper into how these themes interact and influence each other. I will explore the implications of this interplay for the trajectories of research projects, the outcomes they yield, and the broader understanding of academic collaboration. This transition marks a shift from examining the constituent parts to understanding the whole, considering how academic culture, institutional structures, and interpersonal dynamics collectively shape the landscape of academic research.

Further Research

Continuing (repeating) thematic analysis and adding in ethnographic methodology will help SNAP understand the reasons for the network topological changes. It would be beneficial to interview the GCs team leads or even all team members to enhance the interpretations of the analysis of the social networks.

CHAPTER 4:

CUPID

4.1 Collective Understanding of PI Data

Cumulative advantage is a key driver for the development of scientific stars (Mali *et al.*, 2012, p. 235), a term that refers to a specific network structure. Networks consist of actors (researchers) and the relationships among them (ties) (Mali *et al.*, 2012, p. 216). Social Network Analysis (SNA) provides a framework for understanding these structures, focusing on the relationships among actors within a network (Borgatti *et al.*, 2022, p. 2; Mali *et al.*, 2012, p. 216). The modular structure of researcher networks operates across disciplinary, sectoral, and geographical boundaries (Mali *et al.*, 2012, p. 219; Vacca *et al.*, 2015). These actors, or nodes, can be characterized by various categorical attributes, such as department affiliation, or continuous, like years of geographical distances (Mali *et al.*, 2012, p. 219). The relationship in this context, termed as ties or edges, connects researchers to each other and can be quantified in multiple ways, including the frequency of interactions over a given period (Borgatti *et al.*, 2022, p. 2; Mali *et al.*, 2012, p. 216).

For example, Newman (2001) undertakes a comprehensive study of social networks, specifically focusing on scientific collaborations. Newman leverages the coauthorship of scientific papers as an unbiased and scalable measure for mapping

social connections within the scientific community. Gathered data from multiple scientific databases, such as MEDLINE and the Los Alamos e-Print Archive, Newman (2001) created the network that tied each researcher in the network to all other researchers with whom they co-authored a paper within a five-year window (1995-1999). These ties interlink through common nodes, forming paths and, ultimately, a network. Within this network, frequently interacting actors may form a distinct subgroup (Borgatti *et al.*, 2022, p. 2). Newman (2001) found that researchers tend to collaborate with peers who have gained influence through numerous prior joint projects, following a pattern of preferential attachment.

Co-authorship is a common type of relationship used to study scientific collaboration. In their book chapter, Mali *et al.* (2012) explore the complexities of scientific collaboration using co-authorship networks for their example but highlight various other collaborative activities, such as shared editorship, joint supervision of research projects, collaborative research proposal writing, participation in formal research programs, and the organization of scientific conferences (Mali *et al.*, 2012, p. 213).

Historical grant proposal application data from 2016 and 2020 creates multiple networks, including five-year and yearly networks. Nodes are faculty who collaborate within the given time frame, and edges are formed when any two faculty co-propose. Another grant proposal within the bounds of the network links these faculty to other faculty, creating a co-occurrence network (Borgatti *et al.*, 2022). Faculty who proposed alone are removed from the network because we are examining collaborative proposals. Faculty who did not propose within a single year are removed from the network during network modeling.

The grant proposal network does not reveal the true social relationship between

the faculty. While some faculty take on the role of PI on grant proposals, the reasoning for the role varies. Because of this, all individuals who share a grant together are considered equal, with no particular direction that connects the nodes.

4.2 Methods

Mali *et al.* highlights the foundational elements of modern SNA as identified by Freeman (2004): a focus on structural analysis of actors within social relations, the use of systematic empirical data, extensive use of graphical imagery, and a foundation in formal, mathematical, and computational models (Mali *et al.*, 2012, p. 216). By leveraging SNA, I analyze the web of grant proposal collaboration, indicating how relationships and network structures contribute to developing scientific work. Using network visualizations created using 'igraph' (Csárdi *et al.*, 2024), node and network metrics using the 'network' and 'sna' packages (Butts *et al.*, 2023; Butts, 2023) and exponential random graph models using the 'ergm' package (Handcock *et al.*, 2023) in RStudio, I describe Boise State's grant proposal collaboration networks and how they evolve between 2016 and 2020.

4.2.1 Whole Network Descriptions

The local property of a node in the network is **degree centrality**, defined as the number of ties a node has (Mali *et al.*, 2012, p. 214; Borgatti *et al.*, 2022, p. 171). A high degree centrality takes the shape of a star, where one node has many ties to other nodes compared to most other nodes in the network. Its interpretation can vary based on the nature of these ties (Borgatti *et al.*, 2022, p. 172). A star structure in team science networks may indicate a significant inequality in collaborative offers, as few scientists or scholars receive disproportionate offers to collaborate (Moody, 2004).

The cumulative advantage in science posits that scientists already recognized for their contributions are more likely to gain further recognition and resources (Mali *et al.*, 2012, p. 235). This concept, drawing parallels to the biblical passage in Matthew's Gospel and referred to as "The Matthew Effect," implies a disparity in the distribution of resources and opportunities within the scientific community, where established researchers gain disproportionately more funding and power while emerging scientists face challenges in achieving recognition and success (Mali *et al.*, 2012, p. 235-236). This concept highlights how normal social behaviors can thwart the GCs' investment goal to expand research opportunities across campus.

Networks formed through this preferential attachment suggest a scale-free structure characterized by a power-law degree distribution where burgeoning scientists tend to collaborate with established 'scientific stars,' reflecting the principle of cumulative advantage in science (Mali *et al.*, 2012, p. 215; Vacca *et al.*, 2015). This scale-free structure could indicate a hierarchical network dominated by a few highly connected individuals or "hubs" (Mali *et al.*, 2012, p. 236). One method I use to examine the presence of scientific stars is the **degree distribution**. A declining degree distribution indicates that most network members have few ties, and few members have many ties (Harris, 2014, p. 17).

Betweenness centrality measures a node's frequency along the shortest paths between other node pairs (Borgatti *et al.*, 2022, p. 182). It is interpreted as a node's potential to control or regulate the flow through the network, playing a gatekeeper or broker role (Borgatti *et al.*, 2022, p. 183). With their control over resources and opportunities, gatekeepers play a crucial role in shaping the network's topology (Mali *et al.*, 2012, p. 236). I examine the **betweenness distribution** to identify this

phenomenon.

The **connectedness** score illuminates the level of structural cohesion (Borgatti *et al.*, 2022, p. 201-203). Comparing the connectedness across each year's network depicts the change in structural cohesion of the grant proposal network over time. Analysis from degree distribution and connectedness could be used to intentionally connect researchers across diverse modules, such as spanning structural holes and counterbalancing preferential attachment, as Vacca *et al.* (2015) showcase. The potential of network interventions is to overcome inherent biases in collaboration patterns and to bridge gaps between disparate scientific communities. Vacca *et al.*'s (2015) approach offers a pragmatic pathway for fostering cross-disciplinary team science and enhancing the cohesion and diversity of scientific research networks.

I use Bolger (2021) degree of interdisciplinary research by evaluating disciplinary distance in the grant proposal network (see introduction). I evaluate co-grant proposals across distinct super-disciplines (e.g., an ecologist working with a social scientist) (Bolger, 2021). This categorization distinguishes collaborations spanning 'hard' sciences (natural and applied sciences) and 'soft' sciences (social sciences and humanities), offering a more granular understanding of interdisciplinary research dynamics (Bolger, 2021).

The analysis of subgroups and the overall network structure allows for the examination of shared attributes, offering insights into the collaborative dynamics in scientific communities (Borgatti *et al.*, 2022, p. 2-3,214). Research specialties can be identified as a cluster of collaborating scientists responsible for producing a significant number of innovative concepts and ideas (Moody, 2004; Vacca *et al.*, 2015). Collaboration within disciplines often leads to the emergence of distinct clusters within re-

search collaboration networks, indicative of a small-world network structure marked by high local clustering and minimal steps between clusters (Mali *et al.*, 2012, p. 215; Vacca *et al.*, 2015). This structure contrasts with a cohesive core, characterized by an increasing trend of authors from various disciplines collaborating with each other (Moody, 2004). I use network visualizations showing the researcher's affiliated college attribute to illuminate possible disciplinary and short-distance interdisciplinary clustering (Bolger, 2021). The grant networks did not allow for short-distance examination because there are too many departments (93) to analyze effectively.

In addition to network visualizations, network statistics can illuminate interdisciplinary patterns. In small-world networks, there is a notable pattern of dense local connections among actors, yet these actors are separated by only a few intermediary steps (Moody, 2004). This structure contrasts with a cohesive core, characterized by an increasing trend of authors from various disciplines collaborating with one another (Moody, 2004). The **clustering coefficient**, a measure reflecting the network's tendency for triadic closure, is calculated by the ratio of the actual number of closed triangles to the potential number of triads that could possibly contain at least two ties (Goodreau *et al.*, 2009). Interestingly, a network's propensity for clustering often corresponds with increased path lengths, suggesting that as clusters become more defined, the distance between separate clusters can grow (Mali *et al.*, 2012, p. 199). Networks with clusters that cross super-disciplines form "invisible colleges" that drive the intellectual and creative output of the scientific community (Mali *et al.*, 2012, p. 236). The application of Exponential Random Graph Models (ERGMs), discussed below, allows for modeling this local clustering phenomenon within the network.

Density is a fundamental concept that offers insight into a network's overall

structure and interconnectivity. Norton *et al.* (2017, p. 6) define density as the "ratio of the number of actual links to the number of possible links in the network." This ratio provides a quantitative measure of how interconnected the individuals within the network are. Borgatti *et al.* (2022, p. 195-196) further explains that density indicates the likelihood of any two individuals within the network being connected.

Lusher *et al.* (2013, p. 41) assert that the network structure is a product of the social process that produced it and cannot be assumed to be known a priori. This statement highlights that network density often results from the underlying social interactions and processes. In the framework of ERGMs, density is closely linked to the edges term.

4.2.2 Exponential Random Graph Models

The landscape of SNA has been profoundly transformed by the introduction of ERGMs (Mali *et al.*, 2012, p. 218). ERGMs are a specific category of statistical models that articulate the likelihood distribution of network graphs, premised on the assumption that network connections form patterns or configurations that recur more frequently than chance would predict (Harris, 2014, p. 33). These configurations vary broadly, offering adaptability for various contexts, with a positive parameter value indicating a configuration's propensity to occur more often within the network data (Caimo & Gollini, 2020, p. 2).

The edges term in ERGMs resembles the intercept term in logistic regression models (Harris, 2014, p. 52-53). The significance of this term reveals if the network's density deviates from a random network's expected density (Harris, 2014, p. 52-53). The edges term in an ERGM is translated into a probability, showing the likelihood of any two nodes in the network being connected (Harris, 2014, p. 52-53). This

probability, reflective of the network's density, indicates the extent to which ties in the network are not randomly formed.

The null model of an undirected network, described by Harris (2014, p. 39-47), only includes a single edges term representing the number of connections in the network. This model sets a baseline by capturing the network's overall propensity to form edges (its density) while disregarding other structural features. The statistical significance of the edges term in more complex ERGMs, implies that the network's structure is not random but is likely influenced by underlying principles (Harris, 2014).

In developing the ERGMs for this study, I adopt a methodical, stepwise approach to integrate additional nodal attribute terms. To assess the fit of these progressively complex models, I utilize the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). These criteria serve to evaluate model fit, balancing the deviance reduction against the complexity introduced by additional parameters, thereby penalizing over-parameterization (Harris, 2014, p. 63). Terms that contribute to a reduction in AIC or BIC values are maintained in subsequent model iterations. The construction of these models follows a deliberate sequence, aligned with the order of term introduction as detailed below. This sequencing ensures that the analysis prioritizes terms of paramount relevance to the objectives of this study.

Dyadic Independence Terms

As Lusher *et al.* (2013, p. 22) describe, local network configurations are hierarchically nested structures ranging from dyads, formed by a single tie between two nodes, to more complex formations like stars and triads. In this framework, interaction terms for nodal attributes, as Harris (2014) noted, play a crucial role, especially in analyzing dyadic relationships where the attributes of both nodes are considered. Among

these, homophily, the tendency of nodes sharing an attribute to form connections, is a prevalent concept.

Goodreau *et al.* (2009) examine friendship networks, demonstrating the use of several ERGM terms. They explain selective mixing as the propensity of individuals to form connections based on shared attributes (Goodreau *et al.*, 2009). They define **uniform homophily** as the tendency to form ties with others who have similar (homophily) or different (heterophily) attributes (Goodreau *et al.*, 2009).

To evaluate the grant proposal network for long-distance interdisciplinary collaboration (Bolger 2021), I first investigate uniform homophily using the '*nodematch*' term. The '*diff = TRUE*' argument separates parameters for each college category, allowing the model to capture the propensity for faculty within the same college to co-propose more than would be expected by chance. Each college's statistics quantify the extent of collaborative grant proposal engagement among faculty within the same college. An affirmative coefficient indicates homophily, signifying discipline-centric or "short-distance" interdisciplinary collaborations. Conversely, a negative coefficient implies heterophily, suggesting "long-distance" interdisciplinary collaborations. The working hypothesis posits that faculty members tend to co-propose with other faculty members within their own college.

Another selective mixing term that Goodreau *et al.* (2009) describes is **differential homophily**, a propensity to form ties specific to individual categories. The likelihood of forming a tie depends on a particular attribute that differs across various categories of that attribute. As an illustration, Lane *et al.* (2020), investigated the use of Evidence-based Instructional Practices (EBIPs) in college STEM courses, examining the communication ties relative to EBIP usage among instructors. Their

findings revealed distinct interaction patterns based on EBIP familiarity, suggesting a nuanced picture of knowledge diffusion (Lane *et al.*, 2020). Similarly, my study assigns a quartile attribute based on co-proposal counts to explore differential homophily within the grant proposal network.

I aim to determine if researchers who frequently co-propose grants tend to collaborate with others with similar co-proposal activity. I explore the concept of differential homophily within these quartiles using the '*nodemix*' term. This approach allows me to examine whether there is a tendency for high proposers to collaborate with other high proposers, which could indicate a "rich getting richer" phenomenon. Conversely, if high proposers frequently collaborate with low proposers, this might suggest a mentorship dynamic. If the implications of these patterns are significant, they potentially indicate disparities in resource distribution and opportunities within the scientific community.

Dyadic dependence Terms

Transitioning from this exploration of selective mixing, the study also considers the influence of individual characteristics on the propensity to form collaborative ties. **Sociality** captures individuals' intrinsic tendencies to form friendships (Goodreau *et al.*, 2009). It is influenced by various factors such as personality, sociodemographic characteristics, or even external circumstances. Goodreau *et al.* (2009) considered sociality a social process contributing to the outcome, degree. I examine the effect of a faculty member's college on their propensity to co-propose using the term '*nodefactor*'. Each college has statistics, effectively measuring how much more or less likely faculty in the specified college are to co-propose on a grant compared to the reference college.

I complement the AIC and BIC model fit assessments with a comparison of network characteristics between the observed data and simulated networks, following the methods by Harris (2014, p. 63-70). This comparison reveals a notable misalignment in the degree distribution and the distribution of edgewise shared partners, underscoring the necessity for incorporating dyadic dependence terms.

Dyadic independence ERGMs, which include only nodal attribute terms akin to traditional logistic regression, postulate that the probability of a tie is contingent solely upon the attributes of the actors involved, with tie values being mutually exclusive (Goodreau *et al.*, 2009). This is congruent with maximum pseudolikelihood estimation (MPLE) mirroring maximum likelihood estimation (Goodreau *et al.*, 2009).

Nevertheless, such conventional statistical models presuppose the independence of observations, a notion at odds with the complexities of human social behavior, which is multifaceted and intention-driven (Lusher *et al.*, 2013). Certain network patterns are important based on specific social science theories, adopting a particular dependence hypothesis and definition for local configurations (Lusher *et al.*, 2013, p. 19). For instance, the likelihood of a tie forming between two individuals can depend on whether they share common ties in the network, reflecting a tendency for triadic closure (Lusher *et al.*, 2013, p. 69-71).

Geometrically weighted terms in ERGMs capture the complexity of social networks by accounting for the dependency structure among ties. These geometric terms reflect high-order dependencies, introducing challenges in estimating model parameters (Lusher *et al.*, 2013, p. 69-71; Hunter *et al.*, 2008). Models with geometrically weighted terms require Markov chain Monte Carlo (MCMC) simulation methods to address model degeneracy (Lusher *et al.*, 2013, p. 71; Hunter *et al.*, 2008, p. 254).

MCMC works by generating a sample of possible networks that could theoretically have generated the observed data, allowing for the estimation of parameters that best represent the underlying social processes shaping the network (Harris, 2014, p. 71; Hunter *et al.*, 2008, p. 254).

The **geometrically weighted edgewise shared partners** (GWESP) and geometrically weighted dyadwise shared partners (GWDSP) terms capture the concept of transitivity in network structures. GWESP how the presence of shared partners between two individuals influences the formation of new ties (Goodreau *et al.*, 2009; Lusher *et al.*, 2013, p. 69-71. Unlike simple triad closure, which might occur through incidental contact, transitivity reflects a deeper process where shared friends or collaborators lead to direct connections based on perceived social value or affinity (Goodreau *et al.*, 2009). By incorporating the GWESP term into the models, I quantitatively assess the network's clustering by considering how much an existing shared co-proposal contributes to forming additional co-proposers.

As Harris (2014, p. 85) explains, a statistically significant GWESP coefficient implies that the likelihood of tie formation between two individuals is higher than expected by chance, given all other factors are held constant. In other words, shared partners significantly increase the chances of two faculty members collaborating on a grant proposal. If the GWESP coefficient were negative, it would suggest a network where shared partnerships are less likely to lead to new ties, possibly indicating a network less driven by collaborative clusters (Harris, 2014, p. 85). In the context of the grant proposal network, a significant positive GWESP coefficient would support the idea that faculty are more likely to co-propose with others who have mutual collaborators, reflecting a tightly knit community where collaboration is fostered through

established connections (Harris, 2014, p. 85). This pattern is characteristic of networks where knowledge and resources are often exchanged within well-defined local clusters, indicating disciplinary research or thematic communities (Mali *et al.*, 2012, p. 236).

Building on my investigation of cumulative advantage, I investigate the network's **geometrically weighted degree** (GWD). GWD is integral for modeling the degree distribution within networks where the presence of higher-degree nodes is given more weight, indicating a network with a greater number of highly connected nodes (Harris, 2014, p. 83).

A node with two ties is a 2-star node, and a node with k ties forms a k-star. Alternating star parameters, or geometrically weighted degree parameters, are used to model the distribution of nodes with varying numbers of ties (Lusher *et al.*, 2013, p. 65-66). These parameters apply weights with alternating signs to different star counts, which regulate the impact of nodes with numerous connections, mitigating abrupt transitions in network density (Lusher *et al.*, 2013, p. 65-66). When significant, these terms indicate that the network structure cannot be dismissed as random; rather, it is shaped by underlying social processes (Hunter *et al.*, 2008).

A significant positive coefficient for a GWD term in an ERGM suggests that the network is more likely to exhibit nodes with higher degrees than would be expected by chance (Harris, 2014, p. 85). This could imply a tendency towards preferential attachment (Harris, 2014, p. 85), where certain nodes act as hubs within the network (Mali *et al.*, 2012, p. 236). Conversely, a significant negative coefficient would suggest an inclination against such hubs, indicating a more uniform or egalitarian distribution of ties across nodes (Harris, 2014, p. 85). However, the nuances of these coefficients

should be interpreted with caution due to the intricate way a single tie can affect the overall shared partner distribution within the network (Harris, 2014, p. 85).

4.2.3 Goodness of Fit

4.3 Analysis

CHAPTER 5:

LOVE

Interdisciplinary teaming conflicts, as outlined in Chapter 2, can cripple scientific productivity and undermine investments. These concerns—crossing disciplinary boundaries, scarcity of time, institutional structures, interpersonal relationships, leadership, and expanding opportunities for equality—form the backbone of my analysis on fostering effective team science networks. Addressing these concerns is pivotal, especially those that span different disciplines and include community stakeholders, are recognized for producing the most impactful work and groundbreaking innovations (Sonnenwald, 2007; Disis & Slattery, 2010; Hart, 2000; Enns *et al.*, 2023; Lieberknecht *et al.*, 2023). Boise State's engagement with the GCs initiative, as its strategic plan to foster a transdisciplinary culture of research, underscores the importance of understanding and mitigating the barriers to effective team science (LaRosa, 2023a).

While the overarching goal of SNAP is to understand faculty collaboration at Boise State in the context of the GCs investments by the DRED, SNAP's goal for the LOVE branch is to determine whether the GCs investments promote exemplary teams. According to Love *et al.* (2021), there's limited research exploring the effectiveness of scientific team support strategies like training and team performance metrics, despite considerable investment in collaborative and interdisciplinary projects. This work will contribute to the growing body of literature on team science interventions.

5.1 Team Support Investments

WORK HERE: Compose Lit review on network treatments: Bland, Norton, Okraku, Bednarek, Valente

Leite & Pinho (2017) outline common inputs and outputs of the research process. Inputs, including human and financial resources, infrastructures, and the body of existing knowledge, lead to outputs ranging from the generation of new knowledge to tangible products like articles, book publications, patents, and training programs for researchers (Leite & Pinho, 2017, p. 94). Leite & Pinho (2017, p. 94) emphasize that different teams aim to produce different outputs, making measuring productivity challenging. They recommend a participatory productivity evaluation process, customized by each team and their stakeholder and re-evaluated as the team evolves (Leite & Pinho, 2017, p. 90). They emphasize the importance of dialogue and discussion to foster a culture of continual assessment and improvement (Leite & Pinho, 2017, p. 85-97). I analyze case study teams' pre-treatment networks, phase one of a longitudinal investigation. I ask: What relationships did these case study team members have at the dawn of the GCs investments? The network descriptions may be used as a baseline for measuring exemplary teams.

I aim to answer the question: Does the Grand Challenges initiative enhance the resilience of interdisciplinary teams in their pursuit of sustaining collaborative, creative scholarly work? The LOVE branch of SNAP tracks case-study teams' network changes. Teams may receive resources and training, only resources, or no network treatments. This study seeks to understand how these investments alter faculty collaboration networks. In this project branch, SNAP replicates the (Love *et al.*, 2021) mid-point survey to investigate the characteristics of successful and unsuccessful col-

laborations in interdisciplinary scientific teams.

5.2 Methods

The LOVE branch derives its foundations from work by Love *et al.* (2021), which investigates the characteristics of an exemplary interdisciplinary research team. Love *et al.* (2021) investigates how scientific productivity, advice, and mentoring networks within an exemplary interdisciplinary scientific team contribute to their success, focusing on the team's training processes and their impact on productivity and expertise. Love *et al.*'s hypothesis suggests a positive correlation between mentoring, advice networks, and scientific productivity, indicating that these elements are integral to the success of interdisciplinary scientific teams. Love *et al.* uses mixed methods, including SNA.

This thesis proposes SNA metrics that could be used for research network productivity evaluation (RNPE), a term used by Leite & Pinho. Examining professional networks such as joint publications, grant proposals, committee involvement, conference participation, and university business becomes a practical approach to measuring scientific productivity.

The primary data source for this study is pre-survey results gathered through Qualtrics (Qualtrics, 2005).

I utilize Love *et al.* (2021) mid-point survey, creating a pre-network treatment survey where the results are formed into 'network' (Butts *et al.*, 2023; Butts, 2023) and 'igraph' (Csárdi *et al.*, 2024) objects for analysis.

5.2.1 Case Study Teams

The survey participants are members of small teams categorized into three types: Leadership, Award, and IRA. Two leadership teams came together to promote the Grand Challenges and did not receive funds or training. The awards devised by the leadership team created the award teams. Award teams received funds ¡$100,000 to conduct a Grand Challenges topic pilot study but did not receive team science training directly. Five Interdisciplinary Research Advancement (IRA) teams each have their own unique thematic drive. Each IRA team received a small quantity of money ($25,000) to build their research network. Additionally, they are receiving the Interdisciplinary Research Accelerator (IRA) network treatment. Networks research predominates in an intramural, interdisciplinary dimension (Mali *et al.*, 2012, p. 220) where nodes are faculty at Boise State. However, the Award and Leadership teams do include Boise State staff, Idaho community members, and local organizations.

Grand Challenges Once funding was determined for the promotion of the GCs, half a million per GC, CRCA needed to determine how to engage faculty (LaRosa, 2023b, personal communication, September 25). Two teams were conceptualized to invigorate faculty involvement in Grand Challenges. These leadership teams emerge as distinct entities, each marked by its unique approach and ethos.

Resource Nexus Leadership The first team, self-assembled and driven by a shared vision, coalesced around the Grand Challenges of the Resource Nexus for Sustainability. This team portrays passionate commitment and close-knit social bonds (LaRosa, 2023b, personal communication, September 25). This passion translated into tangible outcomes, with the team's collective effort resulting in three awards totaling $400,000—a remarkable feat that underscores their dedication and synergy.

Healthy Idaho Leadership Contrasting sharply with the first, the second Leadership team was born out of administrative nomination. Comprising individuals appointed by Deans, this team's genesis was rooted in their employment responsibilities rather than a self-driven initiative. LaRosa describes their approach as expedient and pragmatic, a demeanor that, while effectively accomplishing tasks, lacked the emotive drive of their counterparts (LaRosa, 2023b, personal communication, September 25). "They got the job done quickly," LaRosa notes, alluding to their efficient, albeit dispassionate, method of operation (LaRosa, 2023b, personal communication, September 25). This efficiency bore fruit in two substantial awards, each worth $200,000, demonstrating their ability to deliver results calculatedly. Yet, the sustainability of such a team is inextricably linked to the continuity of funding. Without a regular influx of financial resources, the future of this team hangs in a delicate balance (LaRosa, 2023b, personal communication, September 25). Their existence, shaped and sustained by administrative directives and funding streams, may face dissolution without these elements.

The dichotomy between these two Leadership teams at Boise State University—one fueled by intrinsic motivation and social cohesion, the other by institutional mandate and functional expediency—offers a fascinating glimpse into the varied landscapes of academic collaboration. It underscores how different modes of team formation and the nature of their objectives can shape their immediate outcomes and potential longevity and impact within the broader academic community.

Healthy Idaho Award Team 1

Healthy Idaho Award Team 2

Resource Nexus Award Team 1

Resource Nexus Award Team 2

Resource Nexus Award Team 3

Interdisciplinary Research Accelerator

IRA Food and Fiber Systems

IRA MARESUNEX

IRA Placemaking

IRA U-SIP

IRA Water Energy Human Systems

5.2.2 Metrics

Scientific Productivity

Team Resilience

Interdisciplinary Collaboration

New and Expanded Opportunities

5.3 Analysis

5.3.1 Participant Characteristics

Position

Department

Roster Expansion

Grant Proposal History

5.3.2 Understanding How Network

5.3.3 Knowledge Of Network

5.3.4 Professional Networks

5.3.5 Personal Networks

5.3.6 Network Interactions

cool

CHAPTER 6:

DISCUSSION

6.1 ???

6.2 ???

6.3 Future Research

Network ethnography poses an additional benefit to measuring scientific productivity. Leite & Pinho (2017, p. 95) note that while some researchers worry about the perceived lack of objectivity in qualitative indicators, any indicator can be quantified and analyzed statistically to ensure objectivity.

CHAPTER 7:

CONCLUSION

REFERENCES

Bednarek, Rebecca, Cacciatori, Eugenia, Chalkias, Konstantinos, Rodgers, Rhianna Gallagher, Jarzabkowski, Paula, Kavas, Mustafa, & Krull, Elisabeth. 2023. Delivering impact via the ebb-and-flow of a research team: Reflection on a long-term program of research into a global societal challenge*. *Journal of Applied Behavioral Science*.

Bland, Carole J, Center, Bruce A, Finstad, Deborah A, Risbey, Kelly R, & Staples, Justin G. 2005. A Theoretical, Practical, Predictive Model of Faculty and Department Research Productivity. *Academic Medicine*, **80**(3), 225–237.

Boise State University. 2024 (1). *Goals and Strategies*.

Bolger, Paul. 2021. A study of faculty perceptions and engagement with interdisciplinary research in university sustainability institutes. *Journal of Environmental Studies and Sciences*, **11**(3), 115–129.

Borgatti, Stephen P., Everett, Martin G., Johnson, Jeffrey C., & Agneessens, Filip. 2022. *Analyzing Social Networks Using R*. SAGE Publications.

Butts, Carter T. 2023. *Tools for Social Network Analysis*. 2023-01-24 edn. The Statnet Project, https://statnet.org. R package version 2.7-1.

Butts, Carter T., Hunter, David, Handcock, Mark, Bender-deMoll, Skye, Horner,

Jeffrey, Wang, Li, Krivitsky, Pavel N., Knapp, Brendan, Bojanowski, Michał, & Klumb, Chad. 2023. *Classes for Relational Data*. 2023-01-24 edn. The Statnet Project, https://statnet.org. R package version 1.18.1.

Caimo, Alberto, & Gollini, Isabella. 2020. A multilayer exponential random graph modelling approach for weighted networks. *Computational Statistics and Data Analysis*, **142**(2).

Csárdi, Gábor, Nepusz, Tamás, Traag, Vincent, Horvát, Szabolcs, Zanini, Fabio, Noom, Daniel, & Müller, Kirill. 2024. *igraph: Network Analysis and Visualization in R*. R package version 2.0.1.1.

Dalton, Amaris, Wolff, Karin, & Bekker, Bernard. 2021. Multidisciplinary Research as a Complex System. *International Journal of Qualitative Methods*, **20**.

Dalton, Amaris, Wolff, Karin, & Bekker, Bernard. 2022. Interdisciplinary Research as a Complicated System. *International Journal of Qualitative Methods*, **21**(5).

Disis, Mary L., & Slattery, John. 2010. The road we must take: Multidisciplinary team science. *Science Translational Medicine*, **2**(3), 22–31.

Duysburgh, Pieter, Naessens, Kris, Konings, Wim, & Jacobs, An. 2012. Collaboration in a multidisciplinary, distributed research organization: A case study. *Higher Education Policy*, **25**(9), 267–288.

Enns, Jennifer E., Brownell, Marni, Casidsid, Hera J. M., Hunter, Mikayla, Durksen, Anita, Turnbull, Lorna A., Nickel, Nathan C., Levasseur, Karine, Tait, Myra J., Sinclair, Scott, Randall, Selena, Freier, Amy, Scatliff, Colette, Brownell, Emily, Dolin, Aine, Murdock, Nora, Mahar, Alyson, Sinclair, Stephanie, & Partnership,

SPECTRUM. 2023. The Full SPECTRUM: Developing a Tripartite Partnership between Community, Government and Academia for Collaborative Social Policy Research. *Gateways: International Journal of Community Research and Engagement*, **16**(6), 1–16.

Glied, Sherry, Bakken, Suzanne Bakken, Formicola, Allan, Gebbie, Kristine, & Larson, Elaine L. 2007. Institutional Challenges of Interdisciplinary Research Centers. *Journal of Research Administration*, **38**, 28–36.

Goodreau, Steven M, Kitts, James A, Butts, Carter, van Duijn, Marijtje, Gile, Krista, Hamilton, Deven, Goodreau, Pavel Krivitsky Steven, & Morris, Martina. 2009. Birds of a feather, or friend of a friend? Using exponential random graph models to investigate adolescent social networks. *Demography*, **46**, 103–125.

Handcock, Mark S., Hunter, David R., Butts, Carter T., Goodreau, Steven M., Krivitsky, Pavel N., & Morris, Martina. 2023. *ergm: Fit, Simulate and Diagnose Exponential-Family Models for Networks*. The Statnet Project (`https://statnet.org`). R package version 4.6.0.

Harris, Jenine K. 2014. *An introduction to exponential random graph modeling*. Vol. 173. Sage Publications.

Hart, Richard L. 2000. Collaborative publication by university librarians: An exploratory study. *The Journal of Academic Librarianship*, **26**, 94–99.

Huang, Ying, Liu, Xiaoting, Li, Ruinan, & Zhang, Lin. 2023. The science of team science (SciTS): An emerging and evolving field of interdisciplinary collaboration. *El Profesional de la Información*, **32**(3), 1–26.

Hunter, David R., Goodreau, Steven M., & Handcock, Mark S. 2008. Goodness of fit of social network models. *Journal of the American Statistical Association*, **103**(3), 248–258.

Jonsen, Karsten, & Jehn, Karen A. 2009. Using triangulation to validate themes in qualitative studies. *Qualitative Research in Organizations and Management: An International Journal*, **4**(8), 123–150.

Lane, A. Kelly, McAlpin, Jacob D., Earl, Brittnee, Feola, Stephanie, Lewis, Jennifer E., Mertens, Karl, Shadle, Susan E., Skvoretz, John, Ziker, John P., Couch, Brian A., Prevost, Luanna B., & Stains, Marilyne. 2020. Innovative teaching knowledge stays with users. *Proceedings of the National Academy of Sciences of the United States of America*, **117**(8), 22665–22667.

LaRosa, Jana. 2023a (10). *Interdisciplinary Research Accelerator*.

LaRosa, Jana. 2023b (Sept.). *Interview with Lorraine Gaudio*. Zoom meeting. Personal communication, September 25.

Leite, Denise, & Pinho, Isabel. 2017. *Evaluating Collaboration Networks in Higher Education Research: Drivers of Excellence*. Springer International Publishing.

Lieberknecht, Katherine, Houser, Heather, Rabinowitz, Adam, Pierce, Suzanne A., Rodríguez, Lourdes, Leite, Fernanda, Lowell, Jonathan, & Gray, Jennifer Nelson. 2023. Creating meeting grounds for transdisciplinary climate research: the role of humanities and social sciences in grand challenges. *Interdisciplinary Science Reviews*, **48**, 585–607.

Love, Hannah B., Cross, Jennifer E., Fosdick, Bailey, Crooks, Kevin R., VandeWoude, Susan, & Fisher, Ellen R. 2021. Interpersonal relationships drive successful team science: An exemplary case-based study. *Humanities and Social Sciences Communications*, **8**(12).

Lusher, Dean, Koskinen, Johan, & Robins, Garry. 2013. *Exponential Random Graph Models for Social Networks: Theory, Methods, and Applications*. Cambridge University Press.

Lyall, Catherine, & Fletcher, Isabel. 2013. Experiments in interdisciplinary capacity-building: The successes and challenges of large-scale interdisciplinary investments. *Science and Public Policy*, **40**(1), 1–7.

Lyall, Catherine, Bruce, Ann, Marsden, Wendy, & Meagher, Laura. 2013. The role of funding agencies in creating interdisciplinary knowledge. *Science and Public Policy*, **40**, 62–71.

Mali, Franc, Kronegger, Luka, Doreian, Patrick, & Ferligoj, Anuška. 2012. Dynamic scientific co-authorship networks.

Moody, James. 2004. The structure of a social science collaboration network: Disciplinary cohesion from 1963 to 1999. *American sociological review*, **69**(4), 213–238.

Newman, M. E.J. 2001. The structure of scientific collaboration networks. *Proceedings of the National Academy of Sciences of the United States of America*, **98**(1), 404–409.

Norton, Wynne E, Lungeanu, Alina, Chambers, David A, & Contractor, Noshir. 2017.

Mapping the Growing Discipline of Dissemination and Implementation Science in Health. *Scientometrics*, **112**, 1367–1390.

Okraku, Therese Kennelly, Sciabolazza, Valerio Leone, Vacca, Raffaele, & McCarty, Christopher. 2017. A mixed method approach for identifying emerging fields and building collaborative teams: Leveraging network ethnography to design experimental interventions. *Ethnographic Praxis in Industry Conference Proceedings*, **2017**(11), 177–196.

Piqueiras, Eduardo, Stanley, Erin, & Laskey, Allison. 2023. Mitigating challenges of collaborative science through team ethnography. *Journal of Organizational Ethnography*, **12**(7), 162–180.

Qualtrics. 2005. *Qualtrics*.

Research and Economic Development. 2024. *Grand Challenges*. Boise State University. Retrieved on January 31, 2024.

Rittel, Horst W., & Webber, Melvin M. 1973. Dilemmas in general theory of planning. *Policy Sciences*, **4**, 161–169.

Sonnenwald, Diane H. 2007. Scientific Collaboration. *Annual Review of Information Science and Technology*, **41**(10), 643–681.

United Nations Department of Economic and Social Affairs. 2024. *Sustainable Development*. Retrieved on January 9, 2024.

Vacca, Raffaele, Mccarty, Christopher, Conlon, Michael, & Nelson, David R. 2015. Designing a CTSA-Based Social Network Intervention to Foster Cross-Disciplinary Team Science. *Clinical and Translational Science*, **8**(8), 281–289.

APPENDIX A:

EXAMPLE OF AN APPENDIX

Here are two examples of the math format:

$$|T| \sim \exp(-\tilde{R}(k)x), \tag{A.1}$$

and

$$I_t(x,t) = \exp(-Bvt/\ell_s - vt/\ell_a) \exp\left(Bvt/\ell_s(1 - 1/2(x/vt)^2)\right) \times (2\pi\ell_s/Bvt)^{-1/2}. \tag{A.2}$$

You can also display the math from expression(A.1) within lines of text: $|T| \sim \exp(-\tilde{R}(k)x)$, or separate without numbers:

$$|T| \sim \exp(-\tilde{R}(k)x).$$