THE DAWN OF ADVANCED COLLABORATIVE PRACTICES: CHARTING TRANSDISCIPLINARY SYNERGIES THROUGH THEMATIC AND SOCIAL NETWORK ANALYSIS WITHIN 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

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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

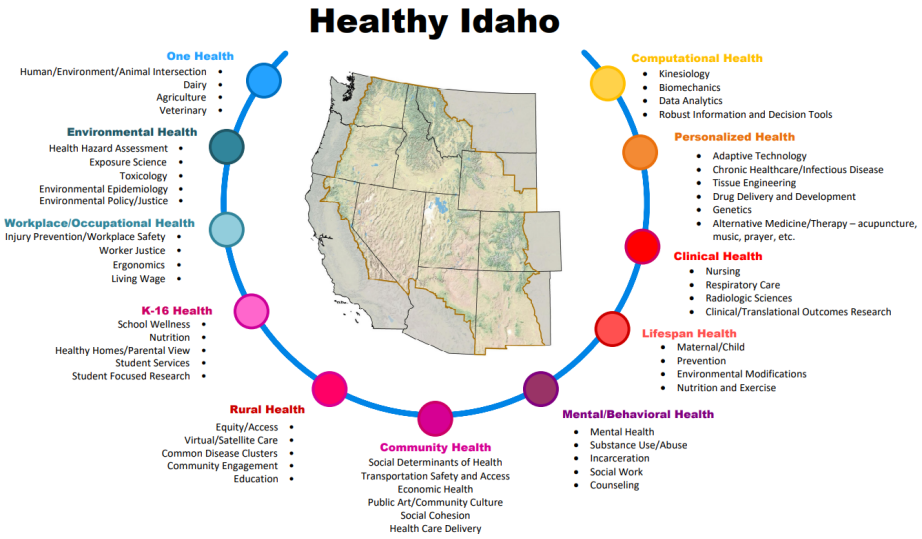

Figure 1.1: The Healthy Idaho GC outlines key areas for collaborative efforts to improve health outcomes across the state. These areas include Public Health, emphasizing the human-environment-animal intersection; Environmental and Workplace Health; K-16 Health, focusing on youth wellness and education; 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).

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 genuinely 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 distances. 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 intro-

duces 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 sub-

optimal 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, transdis-

ciplinary 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 incompatibilities, 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 re-

searchers, 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 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).

Interdisciplinary team members 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 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 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.

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," "profes-

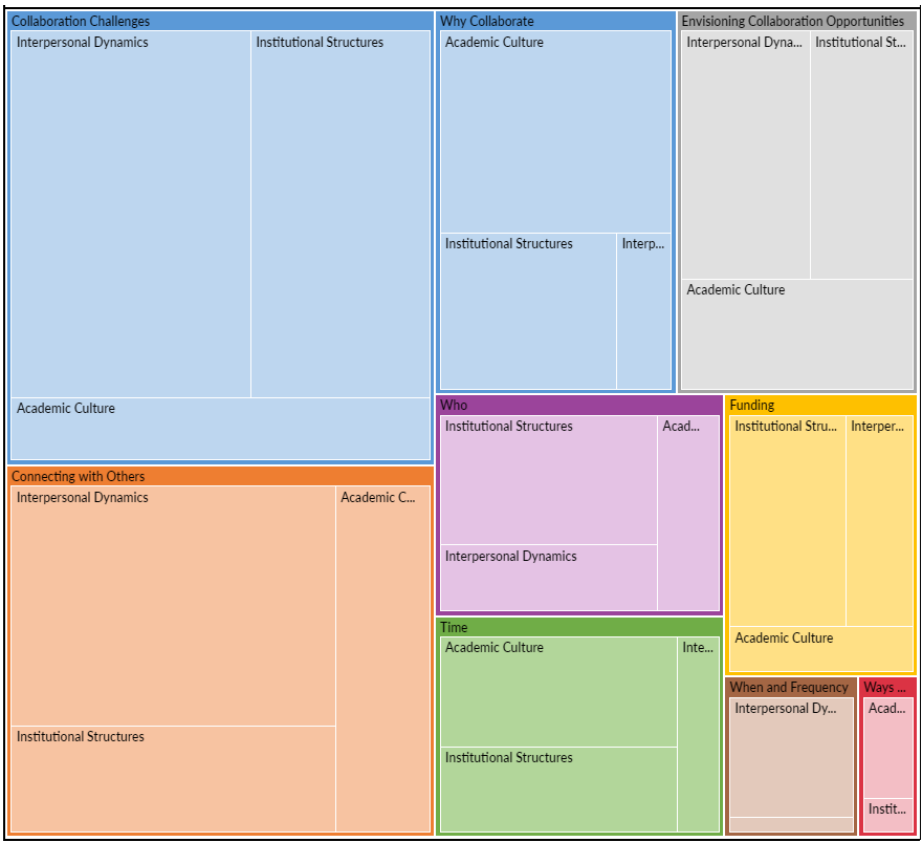

Figure 3.1: The focus group hierarchy chart showing a code comparison by number of coding references

sional 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.

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.

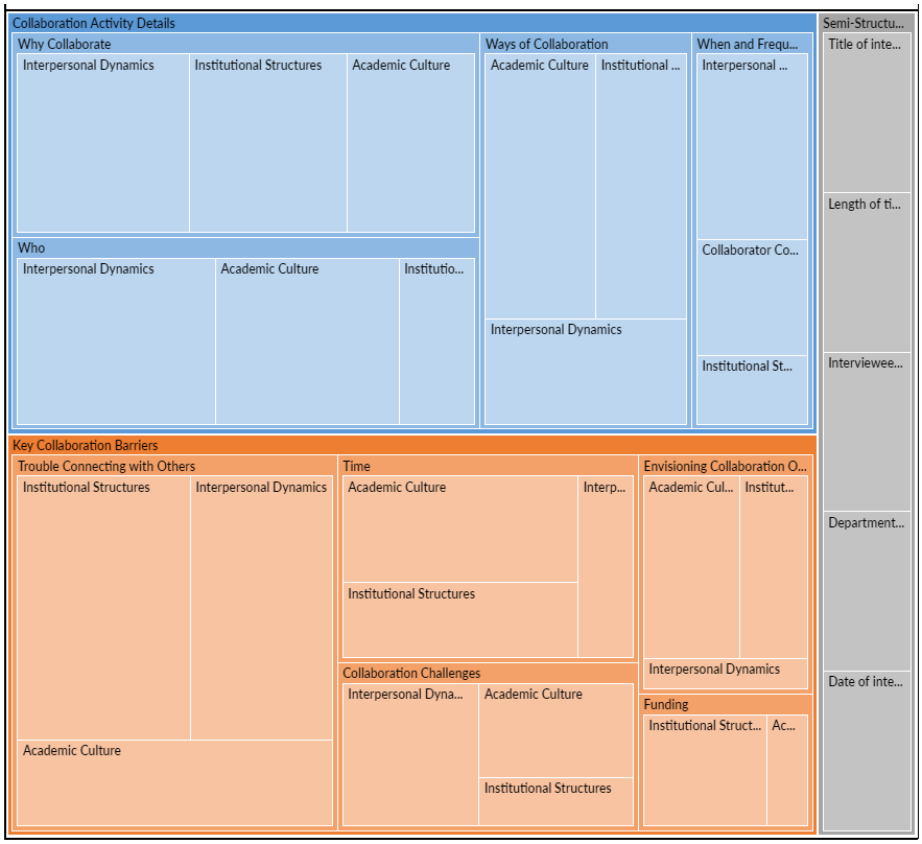

Figure 3.2: The semi-structured interviews hierarchy chart comparing the codes by the number of coding references.

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 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 responsibilities 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 jour-

ney. 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 importance 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. Cindy McCrea points out the benefit of researching with a peer versus a student:

> "You have somebody to bounce ideas off of. You know, 'Which direction should we go with this, and what are the pros and cons.' You can do that with a student researcher, but often they are just a sounding board. They don't have the experience to weigh heavily on those discussions" (McCrea, 2023, personal communication, December 15).

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, respect, 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 dy-

namics 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 (Boise State University, 2024, See goal 4).

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.

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 research 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 net-

work 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 net-

works 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

5.1 Charting the Evolution of Research Collaboration

Initiating network interventions at Boise State signals a new era of creative work. This chapter outlines the dawn of advanced collaborative practices at Boise State, charting the potential within its research teams prior to the infusion of network treatments. The SNAP initiative, particularly its LOVE branch, seeks to assess the impact of the GCs' investments and whether they foster exemplary teams and create broader opportunities within the university's academic landscape. In this thesis, a path is mapped for subsequent analysis of how such treatments influence scientific collaboration, productivity, and the expansion of interdisciplinary opportunities across campus and transdisciplinary opportunities across local, regional, and national interests.

The potential of network interventions, as defined by Valente (2012), moves to enhance organizational performance and facilitate behavior change by intentionally altering network connections. With SNA as a tool, this study aims to propose methods for modifying existing network structures to promote interdisciplinary collaboration. Such interventions are designed to address the biases in collaboration patterns and connect disparate scientific communities (Valente, 2012; Vacca *et al.*, 2015), bolstering

team resilience and diversity within research networks.

Concerns exist about the distribution of resources and opportunities, with programs potentially favoring established faculty (LaRosa, 2023b, personal communication, September 25; Disis & Slattery, 2010; Sonnenwald, 2007), underscores the need for strategic efforts. These efforts ensure the investments align with Boise State's goals to expand a culture of innovation, build scalable structures, and create a collective opportunity with a whole institutional impact (Boise State University, 2024) to ensure that GCs' investments do not inadvertently reinforce existing disparities. These goals can be achieved by constructing new connections and expanding networks for the thematic areas identified by interdisciplinary teams.

Interdisciplinary teaming conflicts not only cripple scientific productivity but also risk the very investments meant to spur innovation, highlighting the urgency of navigating these challenges effectively. These concerns—crossing disciplinary boundaries, scarcity of time, institutional structures, interpersonal relationships, leadership, and expanding opportunities for equality—form the backbone of this 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).

Love *et al.* (2021) research highlights a gap in the literature on the underexplored effectiveness of support strategies, such as training and performance metrics, in enhancing the productivity and expertise of interdisciplinary scientific teams. Love *et al.* (2021) reveal a significant correlation between mentoring, advice networks, and scientific productivity, indicating that specific support strategies can profoundly impact

team success.

The Love *et al.* (2021) study unveils a significant correlation between mentoring, advice networks, and scientific productivity. It illustrates how being part of a team bolsters members' skills, relationships, and professional growth, thus fueling their scientific achievements. This research underscores the transformative power of social dynamics in the knowledge-creation process, with interpersonal relationships at the core of team success (Love *et al.*, 2021). Such insights highlight the shift from individual achievements to collective progress, emphasizing the critical role of nurturing interpersonal relationships within teams. The SNAP project leverages these findings in initiating a rigorous empirical investigation.

This effort aims to assess how intensive research collaborations within the GCs initiative evolve and impact the nature of collaborative relationships over time. By replicating the mid-point survey by Love *et al.* (2021), this thesis seeks to establish a baseline of collaborative relationships at Boise State. The research not only addresses immediate inquiries about interdisciplinary teamwork but also prepares the ground for a detailed examination of how networks transform. Moreover, this methodology seeks to enrich our comprehension of team dynamics, providing insights that benefit both Boise State and the wider academic community, highlighting the effectiveness of targeted interventions in achieving success across a spectrum of interdisciplinary teams.

Building on the foundational insights explored in this introductory section, the subsequent parts of this chapter will delve deeper into the practical application and empirical study of network treatments within Boise State's research ecosystem. This study details the case study teams, emphasizing the range of network treatments they

receive—from comprehensive resources and training to limited or no interventions. It then establishes the criteria for an exemplary team, concentrating on scientific productivity, team resilience, and the capacity to nurture interdisciplinary collaboration that expands academic opportunities across the campus. These criteria guide the analysis of survey data in the subsequent section, focusing on team members' characteristics and the complex networks they form. By comparison of these networks, the study outlines a framework for analyzing the impact of network treatments on fostering productive, resilient, and convergently transdisciplinary research teams. Such analysis sets the foundation for a comprehensive discussion on the potential for institutional collaborative advancement in the following chapter.

5.2 Method: SNA

This study draws its primary data from a pre-survey conducted using Qualtrics (Qualtrics, 2005), leveraging the survey framework established by Love *et al.* (2021). SNAP adapted Love's mid-point survey to design a pre-network treatment survey tailored to this research context. The survey's outcomes are systematically transformed into network objects, utilizing the 'network' (Butts *et al.*, 2023) and 'igraph' (Csárdi *et al.*, 2024) packages in R for comprehensive network analysis. This methodological approach enables the construction of directed graphs, essential for visualizing and analyzing the complex interactions within the research teams.

The analysis hinges on creating directed graphs crafted from survey responses where participants identified their connections to peers within the team. Such connections, or nominations, form the basis of the directed edges in the graphs, indicating the direction of the relationship from the nominator to the nominee. This method highlights the directionality of relationships, which is crucial for understanding the

flow of influence and information among team members, aligning with the techniques suggested by Borgatti *et al.* (2022, p. 16). Further, the analysis considers both in-degree—the count of incoming connections to a node—and outdegree—the count of outgoing connections, enriching the understanding of each team member's role within the network (Borgatti *et al.*, 2022, p. 184).

The concept of eigenvector centrality is also employed, which not only considers the direct connections a node has but also the centrality of those nodes to which it is connected, suggesting that links to highly connected nodes significantly boost a node's centrality score (Borgatti *et al.*, 2022, p. 172-174, 184). This nuanced measure of centrality helps reveal the network's influential researchers based on the premise that not all connections have equal value.

Additionally, the networks in this study are constructed with weighted ties, where the weights might be derived from Likert scale responses or from aggregating multiple types of ties. Given that aggregating data can introduce analytical complexities (Atkisson *et al.*, 2020; Borgatti *et al.*, 2022, p. 44; Domenico *et al.*, 2015; Górski *et al.*, 2017), careful consideration is given to assessing potential distortions this might cause. Through a systematic analysis of the multivariate networks, this study aims to comprehend the intricacies of team dynamics, thus enabling a more profound comprehension of how network interventions could potentially reshape these research communities. By dissecting the layers of multivariate networks, the research strives to capture the depth of team interactions, which informs a deeper understanding of how network interventions might reshape these research communities. The section, "Outcome Measures," delves into how these weighted, directed networks are instrumental in dissecting the structural nuances of team dynamics.

5.2.1 Networks

Understanding How Network

In this study, teams with a clear understanding of how each individual's expertise aligns with the team's objectives are more likely to achieve *scientific productivity* in the upcoming year. To explore this aspect, SNAP adapted a question from Love *et al.* (2021) to gauge team members' perceptions of their colleagues' contributions. Specifically, the survey asked: "Please indicate your level of understanding of how each individual's expertise will contribute to the team," providing responses ranging from "This is my name" to "Strongly Disagree."

Assigning weights to these responses is a method I use to quantify the collective understanding within the team: 'Strongly Agree' indicates a high level of perceived contribution (weight = 3), 'Agree' shows agreement but to a lesser extent (weight = 2), 'Neutral' indicates ambiguity or a baseline understanding (weight = 1), while 'Disagree' or 'Strongly Disagree' suggest a perceived disconnect or lack of contribution, thus not forming a tie (weight = 0). The weightage system's transformation of subjective insights into objective quantitative data enables an in-depth analysis of team dynamics, coherence, and the valuation of each member's expertise within the team framework. These weighted responses then serve as the basis for evaluating the strength of social relationships within the team, which is crucial for assessing the team's potential for future productivity.

Knowledge Of

To assess the depth of knowledge team members possess regarding each other's scientific expertise, this study employs a nuanced approach inspired by Love *et al.* (2021). Participants were prompted to evaluate their understanding of each colleague's expertise, with response options designed to capture a gradient of familiarity—from a precise grasp of a colleague's specific area of expertise to a complete lack of knowledge. These responses, ranging from "I can describe their specific area of expertise very accurately" (assigned a weight of 3) to "I cannot describe their area of expertise at all" (assigned a weight of 0), were then quantified to serve as weighted edges within our network. This quantification process transforms subjective perceptions of expertise into measurable data points, enabling a structured analysis of knowledge depth within the team. Such a weighted approach not only illuminates the varying levels of understanding among team members but also lays the groundwork for evaluating the potential for interdisciplinary collaboration and synergy. By systematically quantifying these interactions, the study more accurately gauges the readiness of the team to engage in *convergent* collaborations that demand a comprehensive mutual understanding of diverse scientific backgrounds.

Professional and Personal Networks

To understand the dynamics of team interactions, this study draws upon the methodology of Love *et al.* (2021), who explored how team members engage with one another across various contexts. Participants in this survey were asked to detail their interactions with fellow team members through a comprehensive list of options, ranging from collaborative efforts like joint publications and grant proposals to more per-

sonal connections such as seeking advice or friendship. Notably, the SNAP project adjusted Love's original questionnaire by excluding the option for "NEW consulting or tech support projects" and delineating "joint publications" from "presentations or conference proceedings" to capture these interactions with greater specificity.

From these responses, individual networks were constructed for each type of interaction, with a directed edge representing each chosen relationship. These edges were assigned a weight of one to signify the presence of an interaction, facilitating the *aggregation* of edges into two multilayer networks: a "Professional" network comprised of scholarly and work-related interactions and a "Personal" network reflecting social and advisory relationships. The Professional network comprises the following networks: Joint Publications, Conferences, Grant Proposals, University Business, Committees, My Mentor, Their Mentor, and Professional Advice. The Personal network comprises Personal Advice, Hang Out, and Personal Friend networks. This dual-network framework offers a rich dataset for exploring the dynamics of team interactions.

5.2.2 Multilayered Networks

A multiplex (multilayered or multivariate) network is a social network formed by layers of different types of interactions (Atkisson *et al.*, 2020, p. 1), such as the Professional and Personal networks described above. Exploring Professional and Personal networks opens a pathway to understanding the layered dimensions of interactions that shape the collaborative climate and foster a cohesive research environment. The motivation to compare single-edge type networks is twofold. To address redundancy in multiplex networks (Domenico *et al.*, 2015) and ensure a comprehensive understanding of social systems (Atkisson *et al.*, 2020), aggregation techniques are employed, allowing for a nuanced analysis that maintains the integrity of social connections

across the network's entire framework.

Aggregation reduces the number of layers while maintaining maximum information about the social system (Domenico *et al.*, 2015). One layer can attribute social connections across the entire multiplex framework (Atkisson *et al.*, 2020). However, Atkisson *et al.* (2020) argue that the multiplexity of networks necessitates a holistic examination to circumvent skewed interpretations that might arise. "Weakly coupled layers behave like separate networks" (Górski *et al.*, 2017, p. 2). Networks with similar edges can be aggregated, whereas dissimilar-edged networks should not (Domenico *et al.*, 2015). It is also poor practice to aggregate disconnected or bridged cliques, as noted by Domenico *et al.* (2015, Supplimantry Table 1) such as creating a single network from all the GCs teams.

Another reason for comparing layers is that evaluating multilayered networks can reveal that specific layers are more important and influential in the multilayered network than others (Górski *et al.*, 2017). Comparing networks can elude to the multifaceted nature of social structures (Atkisson *et al.*, 2020).

Several approaches to exploring multilayered networks include the Quadratic Assignment Procedure (QAP), Exponential Random Graph Models (ERGMs), and a Von Neumann entropy modeling strategy.

Researchers often turn to QAP to identify correlations between network layers, particularly when comparing two matrices (networks) while adjusting for a third. This approach becomes more complex with each additional matrix due to the dependence, similar to multicollinearity in multiple regression (van Duijn & Huisman, 2011, p. 464). Relationships span various forms in professional environments, such as collaborations and social support, making them multidimensional (Lusher *et al.*,

2013, p. 213). Different relational ties, like friendship and advice, are interdependent and can influence one another (Lusher *et al.*, 2013, p. 214).

Chapter 4 introduced ERGMs as a method to address the interdependence within networks. ERGMs can also help uncover how various networks interact and impact the multilayer network's structure (Lusher *et al.*, 2013, p. 115-117). However, longitudinal data is necessary to decide whether one type of tie is likely to lead to another (Lusher *et al.*, 2013, p. 117). An extension to the 'ergm' package allows for the analysis of multilayered networks (Krivitsky, 2023).

However, the small size of team rosters renders multilayered ERGMs unsuitable for analysis at this stage. A third method for comparing multilayered networks boils out of the movement of physicists into SNA, bringing with them new modeling strategies (Mali *et al.*, 2012, p. 218). Domenico *et al.* (2015) detail a method for reducing networks while maximizing distinguishability using Jensen-Shannon distance (JSD) and Von Neumann (entanglement) entropy. An edge in a graph, similar to a pure state in quantum mechanics, exhibits zero Von Neumann entropy (Domenico *et al.*, 2015, p. 2). Higher Von Neumann entropy values in multilayered networks indicate more extensive divergence from a pure state (Domenico *et al.*, 2015, p. 2). Domenico *et al.* (2015) employ a stepwise aggregation process, selecting networks with the lowest JSD to observe changes in relative entropy from no to complete aggregation. While Domenico *et al.* use this method to determine whether an aggregation maximizes distinguishability, this method also illuminates information about the social structure. It is a valuable method for describing and comparing the networks.

Insights into these aggregations and their interrelations may reveal the underlying structure and the social processes that shape interactions. Thus, a tie in one network

can predict a tie in another network. Specific Professional networks will exhibit significant coupling: namely, the Grant Proposals with Joint Publications, University Business with Committees and Conferences networks, as well as My Mentor with Professional Advice networks. This hypothesis is grounded in the logical progression from obtaining research funding (Grant Proposals) to the scholarly dissemination of research outcomes (Joint Publications), suggesting a natural linkage between these activities. Similarly, University Business, Committees, and Conferences are anticipated to be intertwined, reflecting the interconnected nature of administrative and academic duties within university settings. The My Mentor and Professional Advice networks are expected to be coupled due to the mentorship relationship inherently involving the provision of professional guidance.

Conversely, a lack of coupling between My Mentor and Their Mentor networks is predicated on the expectation of concordance—defined by Ready & Power (2021) as the consistency in relationship reporting within a network. Such concordance implies that mentorship nominations should be reciprocal, with each party acknowledging the other's mentorship role, indicating that these networks will not be directly coupled due to the expectation of mutual recognition within the mentor-mentee dynamic.

This study's exploration of multiple and multilayer networks sheds light on the complex relationships of the GCs teams. The forthcoming section will delve into the profiles of survey participants, whose experiences and interactions within these networks will crucially inform our understanding of the initiative's impact on fostering a vibrant research community.

5.3 Methods: Case Study Teams

The survey participants are members of small GCs teams, which are categorized into three team types: Leadership, Award, and IRA. Team formation began with the two leadership teams coming together to promote the Grand Challenges. 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 additional professional development network treatments. Five Interdisciplinary Research Advancement (IRA) teams, each with a unique thematic drive, received a small amount of money ($25,000) to build their research network. Additionally, they are receiving the Interdisciplinary Research Accelerator (IRA) network treatment.

5.3.1 GCs Leadership Teams

Once funding was determined to promote 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

With a budget of $75,000 and a timeline from May 2022 to June 2023 for Phase 1, the Resource Nexus Leadership team aims to catalyze a transdisciplinary ecosystem at Boise State focused on sustainability and resilience (Brand, 2022). Their comprehensive approach includes establishing a shared leadership model, conducting asset mapping and a SWOT analysis to integrate and streamline university efforts, forming

an advisory committee to leverage diverse expertise, and engaging community and academic stakeholders to build a supportive network (Brand, 2022). They plan to document and promote their efforts through multimedia storytelling and a written record, develop a model to address common barriers to transdisciplinary work, and lay the groundwork for Phase II funding distribution (Brand, 2022). This strategic plan fosters collaborative research and creative activity, ultimately leading to more resilient urban and rural systems through the Resources Nexus for Sustainability GC.

The Resource Nexus Leadership team was self-assembled and driven by a shared vision. 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. However, 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 need these elements to avoid dissolution.

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.

5.3.2 GCs Award Teams

The GCs Award Teams represent a mosaic of interdisciplinary collaboration, each interweaving diverse academic disciplines with real-world societal issues. These teams, selected for their compelling projects, embody a shared goal: to address pressing societal questions through a scholarly and socially relevant lens.

The two Healthy Idaho awards were $200,000 each, while the three RNS awards totaled $400,000. The future of these Grand Challenge Teams extends far beyond the initial seed money they receive. This funding, while modest, serves as a catalyst, enabling teams to conduct pilot studies that lay the groundwork for more extensive future research. As LaRosa explains, the journey of these teams involves enhancing their understanding of the expertise required, expanding their partnerships, and eventually seeking larger funding opportunities from federal and state agencies and foundations (2023b, personal communication, September 25).

The Grand Challenge Award Teams are not just funding recipients but incuba-

tors of innovative ideas and collaborative partnerships. Central to the ethos of these teams is the requirement for transdisciplinary partnerships; each includes a strong community component. "Community is part of solving Grand Challenges that need social relevance," she notes, highlighting the necessity of grounding academic research in real-world contexts (LaRosa, 2023b, personal communication, September 25). Including community partners in GCs' research development aid in achieving goal 4, fostering a thriving community (Boise State University, 2024). It also aligns with the idea that academia must promote and support external community partnerships to tackle society's wicked problems (Rittel & Webber, 1973) and achieve the United Nations' SDGs. This transdisciplinary component is strategic, guiding the teams' pilot research on trajectories with potential funding sources and societal impact areas.

Healthy Idaho Award Team: Wildfires and Urban Health

Healthy Idaho Award 1 team, collaborating with St. Luke's Health System in Idaho, is an excellent example of a commitment to advancing academic knowledge and addressing societal challenges in meaningful, impactful ways (Sadegh *et al.*, 2023). This team's endeavor to explore the intersections of climate change and human health, particularly the impact of severe heat and wildfire smoke on vulnerable populations in Idaho, is a poignant illustration of research that resonates beyond academic circles (Sadegh *et al.*, 2023). This research's focus on urban populations in Idaho contributes to global Sustainable Development Goals (SDGs) such as Good Health and Wellbeing by seeking to mitigate health risks associated with environmental factors (United Nations Department of Economic and Social Affairs, 2024). Additionally, it aligns with the Climate Action SDGs by addressing the broader implications of climate

change, including increased temperatures and wildfire incidences (United Nations Department of Economic and Social Affairs, 2024). The project's examination of the negative health effects of climate change offers insights valuable to Idahoans and other regions in the US experiencing similar environmental health challenges (Sadegh *et al.*, 2023). Such insights underscore the project's commitment to Partnerships for the Goals (United Nations Department of Economic and Social Affairs, 2024), demonstrating the potential for local research to inform wider-reaching solutions and foster regional collaboration (Sadegh *et al.*, 2023).

Healthy Idaho Award Team: Public Health Resiliency Building

The Healthy Idaho Award Team 2, in partnership with the Wassmuth Center for Human Rights and the Idaho 97 Project, is pioneering an 18-month initiative aimed at countering violent extremism (VE) through innovative public health and social work practices across 12 communities in Idaho (Hutson *et al.*, 2023). This initiative, embodying the essence of a wicked problem, tackles the intertwined challenges of disinformation, social isolation, and potential violence, necessitating a multifaceted and nuanced approach that integrates education, legal, medical, and mental health sectors to forge community-driven prevention frameworks. The project's complexity is rooted in its causes' intricacy and solutions' lasting impacts, demanding bespoke strategies sensitive to local contexts and potential unintended consequences. Such a comprehensive strategy underscores the project's alignment with the SDGs, specifically targeting Good Health and Wellbeing by addressing health implications of VE, Peace, Justice, and Strong Institutions by fostering peaceful and inclusive communities and Partnerships for the Goals through its cross-sector collaboration (United Na-

tions Department of Economic and Social Affairs, 2024). This collaborative endeavor not only seeks to mitigate the immediate threats posed by VE but also contributes to the broader objectives of sustainable development by promoting wellbeing, justice, and strong institutional frameworks, reflecting a deep commitment to tackling one of society's most entrenched and complex challenges (Hutson *et al.*, 2023).

Resource Nexus Award Team: Idaho Regenerative Ranching and Carbon Projects

The Idaho Regenerative Ranching and Carbon Projects, led by Jared Talley of the School of Public Service, address the wicked problem of aligning ranchers' economic interests with environmental stewardship through carbon sequestration and ecosystem restoration strategies (Research and Economic Development, 2024). This initiative targets SDGs such as Climate Action by enhancing soil carbon storage and Life on Land through ecosystem revitalization while also supporting Decent Work and Economic Growth by providing new economic avenues for ranchers (United Nations Department of Economic and Social Affairs, 2024). The complexity of this issue stems from the need to balance short-term economic benefits with long-term environmental sustainability, navigating the uncertain impacts of land management practices on carbon sequestration and ecosystem health, and embodying the interconnectedness of economic development, ecological balance, and community livelihoods (Research and Economic Development, 2024).

Resource Nexus Award Team: Tribal Energy Solutions

Stephanie Lenhart, an associate research professor in the School of Public Service, leads a project that exemplifies a collaborative model with community partners in research design and implementation aimed at enhancing energy and water resource sustainability in Idaho's remote and rural areas (Research and Economic Development, 2024). By building interdisciplinary capacity and a community network, this initiative directly supports SDGs such as Clean Water and Sanitation and Affordable and Clean Energy, particularly emphasizing the unique challenges and contributions of tribal communities (United Nations Department of Economic and Social Affairs, 2024). The project confronts the wicked problem of ensuring sustainable energy and water resources, which involves reconciling tribal knowledge and community needs with sustainable development practices. This effort highlights the critical role of inclusive, community-driven approaches in achieving long-term sustainability goals, reflecting the project's commitment to Partnerships for the Goals (United Nations Department of Economic and Social Affairs, 2024) by fostering partnerships that tailor solutions to the specific environmental and socioeconomic contexts of Idaho's tribal regions (Research and Economic Development, 2024).

Resource Nexus Award Team: Refugee Farming Resilience

The Refugee Farming Resilience initiative tackles the wicked problem of integrating refugee farmers into urban ecosystems, engaging with the complexities of agricultural adaptation, urban policy, and the integration of vulnerable populations. Led by Rebecca Som Castellano, the project directly contributes to the SDGs, such as Zero Hunger by promoting sustainable agriculture, Sustainable Cities and Communities

through the enhancement of urban ecological systems, and Reduced Inequalities by supporting the inclusion of refugee communities (United Nations Department of Economic and Social Affairs, 2024). The initiative's efforts to create actionable strategies for refugee farmers in collaboration with the city of Boise address the intertwined nature of social, economic, and environmental sustainability, reflecting the project's alignment with the broader aims of the SDGs to foster resilient communities and ensure inclusive participation in sustainable development practices (Research and Economic Development, 2024).

5.3.3 Interdisciplinary Research Advancement Teams

At the heart of Boise State's ambition to elevate its research ecosystem, Interdisciplinary Research Advancement (IRA) teams engage in network interventions. These strategic efforts are crucial for cultivating a culture of interdisciplinary collaboration and driving the university's innovative research agenda forward. The Interdisciplinary Research Accelerator (IRA) training is a multifaceted program designed to augment the research capabilities of Interdisciplinary Research Advancement (IRA) teams. The IRA modules encompass three core engagement activities: Faculty Research Leadership, Strategic Visioning, and Team Science Training. Central to network interventions is developing strong research leadership, addressed through the Faculty Research Leadership module.

These network interventions began by selecting individuals in unique positions capable of catalyzing broader network structural changes. 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 an ideal research leader as regarded highly as a scholar, sponsor, mentor, and peer model. When selecting interdisciplinary leaders, DRED nominated five well-positioned researchers, seasoned in their careers and capable of "floating all boats within a thematic area" (LaRosa, 2023b, personal communication, September 25).

These team leads then work with the CRCA to extend and build their team as part of the **Faculty Research Leadership** program. Conducted by the CRCA, this program focuses on enhancing research leadership skills and has two primary modules: Capacity Building and Strategy. The Capacity Building module exercises network and partnership development, encouraging faculty to forge interdisciplinary connections, spot research opportunities, and engage effectively in the grant proposal process (LaRosa, 2023a). Strategy sessions are consultative and aimed at refining the faculty's approach to research proposal development and strategic project planning (LaRosa, 2023a). This training sought to foster effective research collaboration and an inclusive culture of innovation and discovery.

The IRA network interventions encompass four primary network intervention categories: identification of pivotal individuals (nominate leads), segmentation into groups (build foundational team members), induction to foster interactions (develop relationships), and alterations to the network's structure (expand roster)(Vacca *et al.*, 2015; Valente, 2012). All three core IRA activities work to develop and protect the team's connections.

Team Leads work through the Faculty Research Leadership modules when attending "Office Hours," held by CRCA. Team Leads workshop teaming challenges

and receive planned leadership training (LaRosa, 2023b, personal communication, September 25). During the connective thinking process, team members may assume leadership roles as projects evolve (Disis & Slattery, 2010), aligning with DRED's approach that views all members as potential leaders and active participants in leadership development, contributing to the project's adaptability and success. LaRosa said in the interview, "It isn't necessarily the lead only who attends Office Hours. Whoever is on the team wants to do that kind of work is invited. We build a more distributed leadership structure this way" (2023b, personal communication, September 25). All members are potential leaders and active participants in leadership training, contributing to the project's adaptability and success. Such an approach may prevent issues when leaders must reduce their responsibilities or leave their positions, ensuring continuity and stability within the project (Glied *et al.*, 2007).

The second core IRA activity, **Strategic Visioning** (or Strategic Development and Road Mapping), is orchestrated by The Implementation Group (TIG) (LaRosa, 2023a). This initial phase of the IRA program aims to assist teams in articulating a coherent vision, mission, goals, and objectives (LaRosa, 2023a). It incorporated a consultative process beginning with surveys and interviews tailored to elucidate the individual and collective aspirations, challenges, and potential growth areas for team members (LaRosa, 2023a). The subsequent analysis of these interactions informed the strategic planning process, aligning the individual objectives of team members with their collective goals (LaRosa, 2023a).

The third core IRA activity, **Divergent Science**, is facilitated by external consultants Hannah Love and Ellen Fisher and offers six specialized activities tailored to the needs of the GCs teams or administrators (LaRosa, 2023a). This training covers

crucial aspects of team functionality, such as role clarity, project management, followership, communication, and decision-making, aiming to empower teams to tackle complex research problems effectively (LaRosa, 2023a). Each activity is designed not only to address the practicalities of team dynamics and administration but also to instill values of equity, diversity, and inclusion (LaRosa, 2023a).

Leaders are more successful with project management experience (Sonnenwald, 2007) and high levels of organization (Disis & Slattery, 2010). Project managers alleviate burdensome leadership responsibilities (Sonnenwald, 2007). The IRA teams are assigned a project manager who helps relieve minor administrative tasks (LaRosa, 2023b, personal communication, September 25).

In addition to this comprehensive access to the IRA professional development program, the IRA teams received a financial endowment ($25,000). The strategic infusion of financial support and comprehensive, tailored training through the IRA program equips teams with resources and a transformative vision to expand their respective research networks across the institution. These network treatments should result in a robust foundation for grant application(s) to fund the infrastructure of an emerging research center, facilitating its trajectory toward becoming an innovative research hub within Boise State.

IRA Food and Fiber Systems

The IRA team, led by Som Castellano *et al.*, zeroes in on the complex sustainability issues within Idaho's food and fiber systems, facing ecological, social, and economic challenges. Concentrating on the agrifood system's entirety—from production and processing to marketing, consumption, and waste—the team aims to uncover and

address sustainability obstacles such as significant contributions to climate change, soil erosion, and exploitation of resources and labor (Som Castellano *et al.*, 2022). These intricate challenges they tackle are emblematic of wicked problems due to their ecological, social, and economic interconnectedness and the complex repercussions each solution might generate (Rittel & Webber, 1973). This multifaceted problem defies straightforward solutions, as addressing one aspect can inadvertently affect another, necessitating a nuanced approach that considers stakeholders' diverse and often conflicting interests, including marginalized voices like small-scale producers and laborers. The team's work navigates the ecological changes and their intersections with political, economic, social, and cultural dimensions to emphasize the empowerment of these marginalized voices (Som Castellano *et al.*, 2022). This approach fosters a comprehensive understanding of these systems' sustainability challenges and opportunities, guiding them toward meaningful policy changes and innovations for sustainability (Som Castellano *et al.*, 2022).

IRA Materials Resources Sustainability Nexus (MARESUNEX)

The IRA MARESUNEX team at Boise State is committed to fostering a sustainable and equitable materials economy through innovative solutions in Idaho (Crowley *et al.*, 2022). Their work aims to balance ecological sustainability, social justice, and economic viability, focusing on the lifecycle of materials from sourcing to disposal, informed by STEM disciplines (Crowley *et al.*, 2022). Central to their mission is developing partnerships that bridge rural communities' values and traditions with scientific and technological advancements (Crowley *et al.*, 2022). These collaborations focus on mining communities that are pivotal in extracting critical battery elements,

aiming to integrate public inputs for better regional outcomes (Crowley *et al.*, 2022). MARESUNEX initiatives include creating educational and career pathways in STEM for rural students, working with industry to support the green energy economy, and engaging in policy discussions to ensure that development considers the needs and impacts of local and regional communities (Crowley *et al.*, 2022). By emphasizing inclusivity and respect for diverse populations, the team dismantles barriers. It fosters mutual engagement between rural and urban communities, thus contributing to the global pursuit of environmental sustainability and justice for all involved parties (Crowley *et al.*, 2022).

IRA Placemaking

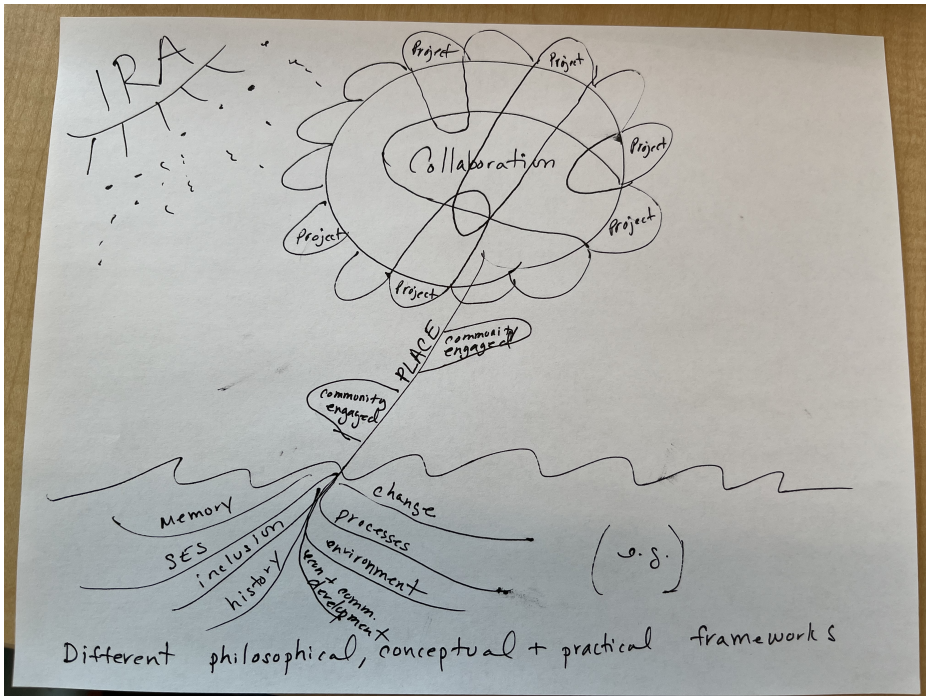

Figure 5.1: The white paper by the IRA Placemaking team presents an illustrative conceptual diagram that metaphorically represents the structure and function of their interdisciplinary thematic space.

The Placemaking team created a different kind of white paper, which was interpreted in this analysis. At the roots, they have foundational elements such as memory, socioeconomic status (SES), inclusion, history, economy, community development, environment, process, and change. These roots may signify the deep-seated factors that nourish and sustain the "place" that forms the stem, indicating the central focus of their efforts on the physical and social aspects of community spaces. The leaves, denoting community engagement, suggest the organic growth and outreach necessary for the projects to thrive. The petals represent disciplines, and the core of the flower, where these disciplines converge, symbolizes the notion that collaborative efforts are central to the team's initiatives, with diverse projects branching out from this collaborative hub. The sun, labeled as the IRA training modules, shines over the entire structure, suggesting that the IRA's guidance and resources are the light that energizes and supports the team's growth and flourishing. The title "Different philosophical, conceptual + practical frameworks" implies that various theoretical and methodological approaches underpin the projects, each tailored to address the unique aspects of placemaking within their contexts.

This artistic representation encapsulates the complexity of Placemaking, highlighting that it is not only multidimensional, encompassing various social and environmental factors, but also dynamic, requiring ongoing engagement and adaptation. The image communicates that the IRA Placemaking team's work is deeply rooted in community and environment, seeking to create sustainable and inclusive places through a collaborative, well-supported research and action process.

IRA Use-Inspired Science to Inform Practices (USIP)

The USIP team promotes sustainable land management and fosters community well-being through science-driven practices. Central to their approach is the integration of local knowledge with the capabilities of private and government sectors to innovate natural resource and human capital management (Forbey *et al.*, 2022). By engaging academia, government, and industry, the team aims to generate science-informed solutions, develop a skilled workforce, and transform systems into inclusive, sustainable practices (Forbey *et al.*, 2022). This collaborative effort aligns with the NSF's goal of advancing global STEM innovation. It is geared towards catalyzing structural changes within partner organizations, overcoming implementation barriers, and defining future workforce competencies (Forbey *et al.*, 2022). During the 2023 spring semester, they were focused on forging ties with NGOs and private entities, leveraging use-inspired research to prepare a career-ready STEM workforce and create innovation-conducive environments, particularly in the natural resources sector (Forbey *et al.*, 2022).

IRA Water Energy Human Systems

The IRA Water Energy Human Systems team is shaping a sustainable future for the American West's water-energy-human nexus, emphasizing harmony in a region undergoing climatic and social shifts (Flores *et al.*, 2022). Their work involves partnering with communities affected by the legacies of settler colonialism to co-develop solutions for water quantity and quality challenges exacerbated by climate change (Flores *et al.*, 2022). The team seeks to reconcile the region's environmental signals, like diminishing snowpacks and erratic precipitation, with the need for equitable resource

management (Flores *et al.*, 2022). By advancing predictive capabilities for water systems and integrating diverse data into community-specific knowledge systems, they aim to facilitate informed decision-making and equitable, just resource distribution in the Intermountain West's varied economic and social landscape (Flores *et al.*, 2022).

5.4 Methods: Outcome Measures

Leite & Pinho (2017) outline typical research process inputs and outputs. Inputs, including human and financial resources, infrastructures, and the body of existing knowledge, lead to outputs ranging from generating new knowledge to tangible products like articles, book publications, patents, and researcher professional development programs (Leite & Pinho, 2017, p. 94). The GCs' investments hope to result in an increased output of interdisciplinary scholarly work.

Leite & Pinho (2017, p. 94) emphasize that different teams aim to produce different outputs, making measuring productivity challenging. The LOVE teams differ in network treatments and outcome goals.

5.4.1 Team Treatment and Outcome Differences

Distinct differences in network treatments and outcome goals delineate the approaches tailored to Leadership, Award, and IRA teams. Each category is uniquely supported, reflecting varied paths to fostering innovation and interdisciplinary collaboration across campus.

As described by LaRosa (2023a), IRA teams receive specialized training and nominal funding, focusing not on immediate project development but on cultivating a thematic network poised for significant future proposals. The objective for these teams is ambitious—securing substantial center funding, such as NSF Science and Technol-

ogy Center awards, necessitating a demonstration of a comprehensive network and research capability (LaRosa, 2023b, personal communication, September 25).

In contrast, award teams receive substantial funding for specific pilot projects without the targeted training IRA teams receive. Award teams aim to leverage these pilot studies towards securing larger, external grant funding, a direct pathway to expanding their research endeavors beyond initial university support (LaRosa, 2023b, personal communication, September 25).

While central to guiding the GCs initiative, the leadership teams do not receive focused training or financial backing as IRA or Award teams. Instead, their influence is more strategic, shaping the initiative's goals. The CRCA offers team science training to all faculty, enhancing collaborative skills throughout the university. However, participation in the specialized IRA program is reserved for IRA teams (LaRosa, 2023b, personal communication, September 25).

Because each team has its own outcome goals, each is treated as a case study, advocating for personalized measures of success. Competition between teams might inadvertently promote differentiation and specialization instead of cross-team collaborations (Duysburgh *et al.*, 2012, p. 276).

5.4.2 Scientific Productivity

An increase in collaborative grant proposals, awards, joint publications, committee involvement, conference participation, and university business measures scientific productivity. The LOVE survey asked participants about their previous professional interactions with teammates, forming networks: Joint Publications, Conferences, Grant Proposals, University Business, and Committees. These networks illustrate the team's prior creative work activities with each other before the team formed. Following the

survey's repetition, SNAP can compare changes in density and average degree over time, measuring the change in the volume of the teams' productivity. The subsequent analysis will detail and compare these networks.

As discussed in the literature review, understanding how team members will contribute poses a significant challenge to interdisciplinary research (Dalton *et al.*, 2022; Piqueiras *et al.*, 2023; Duysburgh *et al.*, 2012). This challenge is echoed by Boise State faculty in qualitative research, where a faculty member expressed difficulty in identifying areas of overlap among disciplines. The LOVE survey participants were asked to rate their understanding of how each team member will contribute to the research team. From this, an Understanding How network is created and analyzed. This network tells of the team's ability to co-create and is a valuable predictor of the team's future productivity.

The Professional networks (Joint Publications, Conferences, Grant Proposals, University Business, and Committees) will measure each team's Scientific Productivity between each other, which is tracked over time. A higher density in these networks implies a more robust pattern of collaboration, suggesting an environment conducive to scientific productivity. Therefore, by tracking density over time, SNAP can discern trends in collaborative behavior, using it as a benchmark to compare the evolving nature of professional interactions within the network. A higher average degree in these networks indicates more extensive collaboration and interaction among team members. Monitoring changes in average degree over time can provide us with a clear understanding of evolving collaboration patterns, with an expected increase aligning with GCs research teams' growing interconnectedness and collaborative efforts.

The historical grant proposal data shows another measure of the team's scientific productivity before joining the team. The 5-year network degree centrality illuminates previous collaborative proposals for each team member. This historical grant proposal network (CUPID) differs from the Grant Proposals network created by the survey as the historical data tells of the individuals' collaborations with any faculty at Boise State, not simply collaborations between team members.

Aside from these conventional SNA metrics, exploring innovative methods for a deeper understanding of scientific productivity within the LOVE teams could be valuable. One such method, Power Graphs, as introduced by Panagopoulos *et al.* (2017), presents an advanced approach to quantifying the creative output of faculty members or research groups. Panagopoulos *et al.* demonstrates this method using ego networks of publication and grant proposal to detect "rising star" individuals and teams. Utilizing both CUPID and CATNIP networks, Power Graphs could highlight the collaborative endeavors of teams. While this thesis employs a different methodology, the potential application of Power Graphs in future research phases promises to enrich the understanding of how collaborative efforts evolve, especially in capturing long-term outcomes.

Exploring scientific productivity through collaborative networks sets the stage for examining the broader impacts of the GCs' investments, particularly their role in nurturing resilient research teams capable of enduring challenges and adapting over time. This focus on resilience, essential for long-term success and adaptability, bridges the discussion from measuring productivity to assessing teams' sustainability and growth potential under the GCs initiative.

5.4.3 Team Resilience

Beyond immediate creative outputs, the GCs' investments aim to foster research teams characterized by enduring resilience and adaptability. The durability of the case study team analyzed by Love *et al.* (2021) over 15 years, marked by team membership expansion, mentorship, and positive interpersonal relationships, exemplifies the resilience sought. These attributes are central to the resilience strategies addressed by the IRA network interventions.

Exploring the strategic recruitment and selection for GCs research teams reveals the complexity of fostering interdisciplinary research (e.g., Bednarek *et al.*, 2023; Duysburgh *et al.*, 2012; Sonnenwald, 2007). The challenge of learning across disciplines in a constrained timeframe may deter prospective members (Piqueiras *et al.*, 2023). The IRA network interventions address these variables for the IRA teams but not the leadership or award teams. SNAP's subsequent study phases can compare teams who received and did not receive the IRA intervention. The study lays the foundation to measure team composition characteristics and interpersonal relationship changes.

Strategic recruitment contributes to team resilience by bringing diverse perspectives and skills necessary for long-term success. However, team member recruitment should be broader than prospective researchers with interests that directly align with the team's long-term goals. As Bednarek *et al.* (2023, p. 9, 11) suggest that the allure for potential team members often stems from broad research interest, which evolves into a passion for the team's mission.

Building on qualitative findings that mutual interests are crucial for initiating collaborations, these interests often translate into reciprocation that might not always

be visible through shared publications but can manifest in the exchange of ideas, division of labor, or advisory roles (White, 2011). Within this context, mentorship plays a pivotal role, acting as a bridge over the interdisciplinary complexities that research teams frequently encounter, facilitating a more seamless integration of diverse disciplinary perspectives and enhancing the overall collaborative process.

New and Expanded Opportunities Across Campus

The pivotal role of mentorship within the GCs initiative is crucial in enhancing educational access and fostering a culture of collaborative research, aiming to create a fair, equitable, and accessible environment for all campus community members. The significance of mentorship in fostering collaborative research is highlighted by Norton *et al.* (2017, p. 9, 12), uncovering that the chance for mentorship by well-connected team members significantly motivates collaboration. Despite the fact that 30% of their survey respondents recognized mentorship as a key factor for collaboration, only 4% viewed mentoring others as a motivation for collaboration (Norton *et al.*, 2017, p. 12). This disparity underscores the need for teams to excel in providing mentorship, enhancing the appeal of joining a research team, and fostering a learning and mutual growth culture.

Aligned with Boise State's strategic goals, particularly in enhancing educational access (Boise State University, 2024), the GCs initiative's mentorship model plays a pivotal role in student education. A mentorship model explored by Love *et al.* (2021) underscores the substantial benefits for team members from various educational stages, from undergraduates to postdocs. This model facilitates personal and professional growth among team members. Notably, this approach has been shown

to encourage student researchers to become core contributors to scientific productivity, illustrating the transformative impact of mentorship on team dynamics and individual careers (Love *et al.*, 2021).

My qualitative analysis in Chapter 3 identified student researchers as important but challenging collaborators as they require significant investments compared to the return and time period of the relationship. Including junior faculty researchers will also benefit the GCs teams because they are better equipped to extend the senior researchers' lines of thought White (2011, p. 274), and they bring fresh perspectives and innovative ideas Valente (2012). Strategic goal 4 aims to enhance employee wellbeing and career growth by advancing the learning and working environment and responsibly using university resources to support collaboration across campus (Boise State University, 2024).

By implementing a strategic approach to team composition and mentorship, the GCs initiative not only seeks to enhance interdisciplinary collaboration but also sets the stage for exploring how these efforts contribute to broadening opportunities for engagement and growth across the university. The following discussion will further examine the initiative's impact on fostering an equitable and inclusive research community.

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 the loudest and most 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 this chapter, 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.

Emphasizing mentorship and experiential diversity within research teams, the remainder of this section outlines an approach for analyzing team membership characteristics. In my analysis section, I apply SNA methodologies to construct a baseline of the current state of research team dynamics. By detailing this methodological preparation, the section ensures a robust foundation for the eventual evaluative analysis that will assess the initiative's success in promoting mentoring within the academic community.

To ascertain their capacity for facilitating mentor-mentee relationships and expanding opportunities across campus, the evaluation considers the experiential diversity of team members. This evaluation is done in several ways. This is approached by

examining the diversity of team members' Boise State positions. Bland *et al.* (2005) point out that faculty of higher rank are more likely to have a history of high research productivity because it is a major criterion for promotion. Survey participants were asked to select their connection to Boise State and allowed to select from the following 15 options: Assistant Professor, Associate Professor, Professor, Lecturer, Assistant Clinical Professor, Associate Clinical, Clinical Professor, Assistant Research Professor, Associate Research Professor, Research Professor, Emeritus Professor, Professor, Professional Staff, Classified Staff, Post-Doctoral Staff, Community Member, Other. If "Other" was selected, the participant had the option of typing their connection to the university in a text box. Teams should contain members from a range of positions, from students to full professors, to ensure there is a range of research productivity experience.

Furthermore, the analysis delves into team members' grant proposal writing experience, utilizing centrality measures in the university-wide grant proposal network to discern prestige and power within the research community. Such measures reveal the range of influence and potential mentorship capacity team members hold (White, 2011, p. 274). Teams exhibiting a broad range of centrality measures likely embody a blend of well-established researchers and emerging scholars, fostering an environment ripe for mentorship and collaboration. However, if most team members have high centrality measures in the historical grant proposal network, then it can be concluded that the GCs' investments are likely empowering the powerful. In this situation, teams would be advised to add more mentee members to obtain experiential diversity.

In assessing the role of mentorship within research teams, the study leverages the

concept of indegree and outdegree centrality in social network analysis to quantify mentor-mentee dynamics. According to Norton *et al.* (2017, p. 10-11), high-status researchers are defined as individuals who are frequently sought for advice by others, who, in turn, are also sought after for advice, establishing a hierarchical structure of expertise and influence. This definition underpins the rationale for using indegree as a measure of mentorship within the "My Mentor" and "Advice" networks. In these contexts, **indegree** represents the number of times an individual is nominated as a mentor or as a source of advice, indicating their status as a valued mentor within the network. High indegree values signify that a researcher is a pivotal source of guidance and knowledge, embodying the qualities of an experienced and influential mentor.

Conversely, **outdegree** in the "Their Mentor" network reflects the extent to which an individual nominates others as mentees, providing insight into the distribution of mentee-seeking behavior within the team. A higher outdegree indicates active seeking of mentees, highlighting the relational dynamics from the perspective of mentors. Similarly, indegree is a measure of team members' status as a valued mentee.

Team characteristics should be not only experience-level diverse but also interdisciplinary. The next section details my planned method to evaluate team characteristics to understand the current discipline diversity of the teams.

Interdisciplinary Collaboration

Interdisciplinarity is a core requirement for the GCs teams (LaRosa, 2023b, personal communication, September 25), necessitating a comprehensive methodological framework to assess the extent of interdisciplinary composition and integration within these teams. Evaluating the teams for interdisciplinary distance involves categorizing team

membership across a spectrum of within-discipline, short-distance, and long-distance interactions (Bolger, 2021), aiming for a balance that fosters diverse and innovative collaborations.

The survey's name-generator question emerges as a tool for addressing the challenge of conceptualizing research within an expansive interdisciplinary framework. This approach encourages participants to nominate significant contributors beyond the provided roster, thereby gauging the team's orientation towards either a disciplinary or a transdisciplinary model of collaboration. The inclusion of external nominees offers valuable insights into the teams' ability to transcend disciplinary boundaries.

The survey name-generator results may indicate a necessity for strategic network interventions to overcome conceptual barriers in recognizing potential interdisciplinary collaborators. Strategic network interventions, as outlined by Valente (2012) and Vacca *et al.* (2015), can also aid in fostering a thriving community Boise State University (2024). Valente outlines tactics such as adding or deleting nodes and links or rewiring existing connections to optimize network structure. Vacca *et al.* (2015) apply these kinds of tactics to a university's scientific collaboration networks to facilitate network interventions. Vacca *et al.* use co-authorship and grant proposal networks to identify unconnected researcher groups, shown as modular structures within network visualizations. They demonstrate the use of the four primary network interventions to enhance the university's network's overall structure while also assembling cross-disciplinary teams (Vacca *et al.*, 2015).

While identifying and connecting researchers from various disciplines is crucial, achieving true interdisciplinary collaboration requires a deeper level of integration,

termed convergence. In the context of interdisciplinary collaboration, "convergence" refers to the process by which team members from diverse disciplinary backgrounds come together to overcome different discipline incompatibilities through a shared understanding and mutual adaptation (Dalton *et al.*, 2022, p. 8).

In Bolger's (2021 study of interdisciplinary research centers, he includes a focus on the convergence of researchers of multiple disciplines. Bolger (2021) does this by surveying the faculty of three well-established research centers, each at a different institution. He found that researchers from the humanities and social sciences were "add-ons" and not fully part of defining questions or generating sustainability research (Bolger, 2021, p. 14). While developing integrated, interdisciplinary knowledge is notably difficult for long-distance collaborations, it may be necessary to obtain grant funding. LaRosa underscores the critical need for authentic interdisciplinary collaboration to meet federal funding requirements, highlighting the challenge of integrating STEM and social sciences in a manner that fosters genuine co-creation of research questions 2023b, personal communication, September 25.

Teams need convergence not only to acquire funding but also to have team resilience. Bednarek *et al.* (2023, p. 10) identified that research membership "stickability" begins with embedding team members into the respective research projects. From the literature review, it is safe to say that convergence is challenging for interdisciplinary teams.

To effectively measure the success of convergence efforts, I utilize several network metrics—outdegree, betweenness, and eigenvector—within the "Knowledge Of" network to quantitatively assess the level of disciplinary integration and mutual comprehension among team members. These metrics offer insights into how well team

members understand each other's fields. It is important to consider the degree of interdisciplinarity of the team when interpreting these metrics. Teams with a higher proportion of within-discipline relationships will, by default, have knowledge of their team members' disciplines. Within-discipline relationships do not contribute to the convergence of disciplines.

In the 'Knowledge Of' network, outdegree centrality reveals the extent to which individuals contribute their expertise, highlighting active knowledge sharing. High outdegree suggests robust dissemination of expertise, pivotal for interdisciplinary learning, yet its impact is most meaningful in teams with diverse disciplines. Betweenness centrality gauges a member's role in bridging diverse knowledge areas, with high scores indicating key individuals who facilitate integration across disciplinary gaps. Low betweenness might imply direct knowledge exchange among members, indicative of a cohesive team understanding. Eigenvector centrality measures the depth of an individual's expertise recognition by central figures in the network, with high values signifying acknowledgment by well-regarded experts, reinforcing the individual's influence and the quality of interdisciplinary interactions. These metrics collectively assess the depth of interdisciplinary integration, the effectiveness of knowledge sharing, and the quality of mutual understanding within teams, underscoring the importance of discipline diversity for genuine interdisciplinary collaboration. For the pre-treatment Knowledge Of network, I predict that those with a high outdegree centrality are also in the Professor position or are in a team that contains more within-discipline relations.

Interpersonal Relationships

The path to effective collaboration often lies in the informal, interpersonal connections that develop over shared experiences, such as lunchtime conversations (Disis & Slattery, 2010). The Personal network is the aggregation of sublayer networks of Personal Advice, Hang Out, and Personal Friend. Strong ties are often associated with more substantial social support and influence (Borgatti *et al.*, 2022, p. 5). The weight is interpreted as the strength of the relationship. In the context of the Grand Challenges initiative, the strength of a faculty member's ties could be predictive of their ability to garner resources and support.

In the Personal network, Degree centrality measures the number of personal interactions individuals have engaged in with their teammates, such as giving personal advice, hanging out socially, and establishing friendships. Uniformity suggests that team members have a balanced level of engagement with each other, with no one person being significantly more central or isolated than others when it comes to personal interactions. A person with a high degree indicates that they are involved in more personal interactions than others.

Eigenvector centrality captures an individual's influence based on both direct personal interactions and the influence of their connections within the team's social fabric. The eigenvector centrality score distribution indicates the level of variation in how individuals are positioned within the network in terms of their connections and the importance of those connections. A higher eigenvector centrality suggests that the individual is not only engaged in numerous personal interactions but is also connected to others who themselves hold significant positions within the network. This can be interpreted as a form of social leverage, where the individual's influence

is amplified by the stature of their associates. In essence, this measure reflects a combination of quantity and quality of social interactions; it signifies that a person is a key player within the network, and their personal interactions carry weight due to the prominence of their connections.

Betweenness centrality identifies individuals who act as bridges within the social structure of the team, facilitating interactions between team members who may not directly connect. High betweenness would indicate a key role in social cohesion and the diffusion of social capital. It suggests that the individual may have unique roles within the team's personal interaction network. When most individuals in a network have a betweenness centrality of zero, it suggests that the network does not have points through which personal interactions must pass.

The Outcome Measures section meticulously articulates a methodological framework for assessing the GCs initiative's impact at Boise State. The initiative aims to enhance scientific productivity, mentoring, transdisciplinarity, convergence, and the quality of interpersonal relationships within each research team. By delineating the specific network treatments and goals for Leadership, Award, and IRA teams, this framework underscores the complexity of evaluating productivity against the backdrop of diverse team objectives. The strategic focus on fostering an environment conducive to interdisciplinary collaboration, mentorship, and the development of resilient research communities forms the crux of the anticipated outcomes.

In the analysis section, the emphasis will be on applying SNA to scrutinize these identified variables in depth. This approach will enable a granular examination of how GCs' investments influence research collaboration at the university. The forthcoming analysis is poised to unravel the initiative's efficacy in promoting an equitable, inclu-

sive, and innovative research landscape by measuring the initial state of the outlined variables. By exploring the dynamics of scientific productivity, assessing the richness of experiential diversity, understanding the depth of mentoring interactions, gauging the breadth of interdisciplinary collaboration, and analyzing the strength and quality of interpersonal relationships, this section aims to provide actionable insights into the transformative potential of the GCs initiative at Boise State.

5.5 Analysis

5.5.1 Participant Characteristics

"Alteration identifies specific individuals whose collaboration is more likely to be successful and to improve the performance of the whole organization by enhancing certain structural properties of single actors or the whole network" (Vacca *et al.*, 2015).

"Local leaders are more sensitive to local conditions and culture" (Valente, 2012). Therefore, network interventions should identify whether early actors are leaders and, thus, are well-positioned to accelerate the spread of interdisciplinary collaboration.

Position

Focus on Mentoring In the preliminary phase of the survey, the second question solicited participants to delineate their association with Boise State by selecting from a comprehensive list of professional designations. The array of options spanned from Assistant Professor to Community Member, encompassing a breadth of academic and some non-academic roles. The heterogeneity of positions within a center is a critical indicator of its capacity to nurture a mentorship-rich environment and catalyze

professional advancement. It is posited that centers distinguished by high scientific productivity are likely to witness their members ascend in their professional trajectories. Moreover, the resilience of a center is reinforced when its constituents derive tangible benefits from their engagement, particularly in terms of career progression. Hence, professional growth is gauged by achieving higher-ranking positions and the longevity and evolution of these advancements over time. This pre-treatment evaluation focuses on the spectrum of positions represented within the center, as this diversity forms the bedrock for potential developmental trajectories.

This exploration into the diverse professional roles within the center naturally leads us to consider the influence of leadership and mentorship on team progression. Leadership that prioritizes mentorship is a vital component for the advancement of a team. According to (Disis and Slattery 2010), teams characterized by an uneven distribution of power may misallocate resources, with investments predominantly benefitting only a select group of individuals. Teams comprising a balanced mix of highly experienced and less seasoned faculty members are better positioned to foster mentorship and professional growth. Subsequent analyses will examine any shifts in team members' positions and the team's expansion.

Department

Roster Expansion

Grant Proposal History

Focus on Mentoring

By analyzing these 5-year networks, where connections are established through collaborative proposals, I can ascertain the prior grant proposal activities of both

individual U-SIP team members and the team collectively. This perspective is instrumental in determining whether the team comprises members who could significantly benefit from the center's resources.

5.5.2 Understanding How Network

5.5.3 Knowledge Of Network

5.5.4 Professional Networks

5.5.5 Personal Networks

5.5.6 Network Interactions

cool

Future Study Concerns

In domain-specific multiplex networks, all individuals must have had the ability to do all of the domains in in the combined network (Atkisson et al. 2020). Our networks almost exclusively includes faculty at Boise State. However, not all individuals are researchers. In IRA MARESUNEX team, one team member's position is "Professional Staff". Additionally, we asked survey participants to tell us if important team members were missing from the roaster. Participants can nominate individuals who are both at BSU or not at BSU. The plan for the mid-network treatment survey is to add these team members and include them. These concerns still need to be addresses.

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.

CHAPTER 6:

DISCUSSION

6.1 ???

6.2 GC Teaming Limitations

6.2.1 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.

6.2.2 Future Research

Publications (CATNIP)

A common network type used to evaluate research collaboration is journal publications. The next phase of SNAP will include an analysis of Boise State's publication network. This can be useful in understanding the collaboration at Boise State as a whole and also in determining each LOVE team's scientific productivity and interdisciplinary publications prior to the network treatments.

Adding Node Attributes to CUPID

An node attribute that could be included in future studies includes attendance of team science training. The CRCA hosts a team science training each semester for any facility member to attend (LaRosa, 2023b, personal communication, September 25). While this study did not include attendance to these programs, the team science training roster is available (See Michelle Grek for CRCA Events Attendance Log). This could be included as a node attribute for GCs team members to help understand differences in team success.

Expanding LOVE Team Roster

However, the forthcoming mid-network treatment survey aims to broaden the team's composition. This survey will include individuals who may not be directly involved in research at BSU, thereby introducing new perspectives and expertise to the team. Addressing the methodological challenges posed by this expansion is crucial. It requires careful consideration to ensure that the integration of new team members aligns with the overarching goals of the U-SIP project and enhances its multidisciplinary approach.

Network ethnography: LOVE team

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

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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:

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