AN ABSTRACT OF THE DISSERTATION OF

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Title: Boundary Dynamics of a Transformative Learning Network: Improving Connection at the Interface of Science and Society.

Abstract approved:

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Transformative learning networks are a specific type of loose network with geographically distributed members and member organizations. They hold particular promise for transformation when both top-down and bottom-up processes have failed to support desired systems-level change. The aim of this dissertation is to build knowledge about the social-interactional processes, roles, and practices that build transformative capacity of a network. I apply poststructural and interpretivist point of view to understand the dynamics of boundaries and boundary work in the National Alliance for Broader Impacts.

The meso-theory herein claims that two types of boundary work - building boundaries and navigating across boundaries - operate in productive tension to expand knowledge resources and increase network authority and influence in the system over time. This suggests that network leaders can dynamically manage boundaries, shifting emphasis between strength and fluidity to support multi-sited and multi-scalar change.

The primary claim of the applied research contribution is that a variety of both structures and interdependent roles and practices work in concert to support transformation across sites and scales. To support this claim, I detail common network substructures, across which critical practices occur and develop a typology of network practices in two distinct,

but interdependent roles. Those in the sojourner role focus on site-based work to shift everyday norms. They demonstrate keen awareness of how their institutions enable and constrain change efforts and contribute that knowledge to the network. Those in an expert role, design networks to support meaningful member engagement opportunities across sites and at the same time build identity and coherence within the network to enable transformation at multiple scales. The expert and sojourner roles generally correspond with boundary building and boundary navigation respectively.

In addition to the focus on boundary dynamics in networks, this study also examines "Broader Impacts" as a path for connecting science and society in a time when the realms of science and other sectors of society need to come together to address increasingly complex social, educational, and environmental challenges. The final contribution describes a manifestation of one of many possible transformative pathways that emerged from and evolves within the network. The concept of helping scientists develop their "impact identity", integrates scholarship in a scientific discipline with societal needs, personal preferences, capacities and skills, and one's institutional context. I understand identity, or a scientists' self-concept, as a productive driver that can improve outcomes for scientists and for society by bridging the gap between them through public engagement activities.

This body of work ties together the theory of morphogenesis from critical realism, boundary concepts from across disciplines, and the landscapes of practice conceptual framework. The aim is to expand understanding about the design and potential of learning networks, which disrupt the status quo to guide change in social-ecological and social-educational systems. The new theory and insights about structures, roles, and practices can inform network and transformation scholars across disciplines. Network leaders, designers, and evaluators can also apply this work to their practice.

Boundary Dynamics of a Transformative Learning Network: Improving Connection at the Interface of Science and Society

by
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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

Julie Risien, Author

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CONTRIBUTION OF AUTHORS

Dr. Bruce Evan Goldstein contributed as the second author of Chapter Two.

Dr. Hannah Gosnell provided pre-submission review of Chapter Three.

Dr. Martin Storksdieck contributed as the second author of Chapter Four.

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1 INTRODUCTION

Networks hold particular promise as social disruptors tackling society's intractable problems. Accordingly, the National Science Foundation (NSF), private foundations, and large institutions have made significant investments in networked approaches to transformational change. Such networks serve as a community for actors with strong commitments to transformational change, but not necessarily the positional authority to implement top-down change. Of particular timely concern is the increasing politicization of science and the perception of science as somehow separate from, rather than integral to, other sectors of society. Many networks are emerging to address the so called science gap.

Here I seek to describe and explain emergent properties that likely contribute to transformational change through the work of one such network, the National Alliance for Broader Impacts (NABI) funded by the NSF. At the highest level, the network seeks to build capacity and bridges to overcome this science and society divide. The focus here is on better describing the role of NABI as a transformative learning network in a complex system and interpreting both the structural and agentic aspects of boundaries toward understanding how networks may contribute to systemic change. My aim is to shed light on the interface of science and society by honing theory about networks, knowledge about practice, and context about the boundaries of science within society.

Guided by principles of participatory action research, I conducted this in-depth case study in collaboration with NABI. Through this collaboration, I was able to directly inform NABI's practice and support the network's reflective and adaptive processes. The results highlight emergent properties that arise from social interactions and network practices that support the work of change agents who, bolstered by the network, disrupt institutional norms and stimulate transformation. Poststructuralist social theories and processual philosophy provide theoretical context and methodological clarity. These theories drive the work towards understanding the whole network as opposed to individualist accounts of change (see Archer, 1996, 2000, 2003, 2010, 2013; Elder-Vass, 2010, 2014; Chia, 1999, 2014; Tsoukus & Chia, 2002). The study is informed deeply by communities of practice theory (Lave & Wenger,

1991; Wenger, 1998; 2000; Wenger, McDermott & Snyder, 2002) and emerging landscapes of practice theory that accounts for complexity across many communities of practice and the boundaries between them (Wenger-Trayner, E. & Wenger-Trayner, B. 2015). The study broadly seeks to 1) contribute meso-level theory on the role of transformative learning networks in complex systems; 2) inform network design and practice across sites and scales; and 3) highlight critical issues about professional identities at the interface of science and society. The later serves as a bridge between this case study and future research.

The five chapters include this introduction, three manuscript style chapters each submitted to peer-review journals, and a concluding chapter that reflects on the major contributions of the dissertation and maps out future research extending from this dissertation. The manuscript option dissertation has an impact on the overall format. Therefore, this introductory chapter provides an overall rational, driving research questions, guiding principles for methods used across the study, and a summary of theory and conceptual framing influential across all three manuscripts. Rational, methods, theoretical and conceptual framing are also included in each of the three manuscripts (Chapters 2, 3, and 4).

1.1 Research Questions

Four questions, oriented around issues of identity, identification, and boundaries, guided inquiry. These questions seek to understand how the practice of networks relate to individual success *and* how the specific interactional experiences and arrangements of individuals may result in emergent network properties associated with systemic change. The questions informed development of research instruments and initial tuning of the interpretive research lens. The research questions guided, but did not limit, the evolution of the study as presented in Chapters Two and Three. Chapter Four does not stem directly from these questions, but rather follows the path of one concept that demonstrated co-learning and collaboration in the network.

1.1.1 Question 1. How does identification with the network support agency?

To understand how an individual process of identifying with the network affects their sense of agency, or a belief in capabilities, to perform as a change agent on their campus will require examination of the network practices supporting identification, how are actors experiencing identification, and how networks augment actors' landscapes of practice.

1.1.2 Question 2. How does shared network identity support collective action?

Study of interorganizational networks and collaborative planning efforts indicate that shared identity is linked to collective action and learning. This question is an effort to illuminate mechanisms for this phenomena. Before searching for links between shared identity and collective action it is important to establish the degree to which actors experience a shared identity and how network practices cultivate, or neglect, shared identity. It is also important to examine specific collective actions around which to examine the role of shared identity.

1.1.3 Question 3. How is boundary work supported by network practice?

This question pursues insights about how the network contributes to actor capacity for the specific skills and practices of boundary work. The question moves beyond agency to document evidence of the specific practices involved in boundary work. Examination into how boundary work is supported through engagement in the network can improve understanding about the roles of networks in building capacity of change agents.

1.1.4 Question 4. How does the network leverage boundaries as an asset?

This question can guide inquiry from two angles. One is to understand how network practices and supports that bring together individuals with different sets of embodied knowledge, each with unique and complex landscapes of practice, mediate and enhance learning between members. Another angle pursues evidence of network-scale learning (where the network itself learns) which may appear in terms of observable adaptive practices responsive to new information or insights emerging from the membership.

1.2 Conceptual Framing

The theoretical and conceptual framing highlights change as emergent and networks as organizational forms that can 1) enhance agency and capacity of actors working to support change at their institutions; and 2) support collective actions across sites and sectors for more systemic change. The NABI network serves as a community for professionals with strong commitments to transformational change, but not necessarily the positional authority to implement top-down change. These actors are "boundary professionals" part of a growing group occupying the "third space" in academic institutions (Whitchurch, 2008, 2009). They work, with some degree of autonomy and agency, to navigate across sites and scales and are increasingly necessary to address contemporary challenges (Whitchurch, 2013). These central actors do not necessarily have authority and resources, but they have the potential to influence policy, practice, and culture (Kezar, 2014) by influencing those with authority and energizing peers. These boundary professionals do not tend to identify with traditional university roles of academics or administrators. NABI, like many similar networks, aims to build new communities, professional identities, and capacities for such actors.

Four primary categories of theoretical and conceptual influence come together in this dissertation. First, identification and boundaries framing draws from several social science disciplines including organizational studies, social learning theory, and science studies. Second, I understand social change of complex systems through the lens of social theories and philosophies, most prominently, morphogenesis. Third, landscapes of practice is a productive framing that has helped to ground my research in the lived experiences of navigating the suite of communities and multiple types of boundaries in complex landscapes. Fourth, the body of work on transformative learning networks has informed decisions to link this dissertation to similar studies of social ecological systems, which utilize principles of resilience, more so than studies of higher education. This dissertation may therefore find useful application across settings of both social-educational and social-ecological systems.

1.2.1 Identification and Boundaries

Identity and identification are powerful constructs for answering the questions "Who are we?", "Who am I?", and "Who am I becoming?" These constructs help people, groups or

organizations situate themselves so they can interact effectively (Albert, Ashforth & Dutton, 2000). Strong identification of actors with networks has been associated with network strength and as a critical pathway to collective action enhancing agentic capacity of actors and collective impacts of networks (Keast & Mandell, 2013; Raab & Kenis, 2009). Development of shared identities is also interpreted to support redefinition of professional practices and roles, moving actors away from the status quo practices toward action (Goldstein & Butler, 2010). The process of identification – which has been described as difficult for change agents and boundary professionals to manage in their complex landscapes of practice – has been linked with co-learning, innovation, and ability to align across scales and communities (Wenger-Trayner, E. & Wenger-Trayner, B., 2015).

Understanding boundaries from both structural and social standpoints is integral to understanding change in complex systems. Boundaries are fluid, socially constructed and continually reconstructed over time (Gieryn, 1983). Boundaries can form around simple points of difference in complex systems – such as those experienced by actors working to change practice and move beyond rigid norms – bringing people together into new social entities such as networks (Abbott, 1995). While boundary work was originally conceived as the work of strengthening and maintaining boundaries that separate distinct groups (Gieryn, 1983), contemporary ideas about boundary work are greatly expanded to include the work of navigating across boundaries, breaking them down, and leveraging boundaries as learning assets (Wenger-Trayner, E. & Wenger-Trayner, B., 2015; Kubiak, et al., 2015; Weber & Khademian, 2008b; Engestrom, 2009).

1.2.2 Morphogenesis, Relational Emergence Theory, and Processual Philosophy of Rhizomatics

In addition to understanding networks from the organizational studies point of view (Keast & Mandell, 2013; Keast, Brown, Mandell, & Woolcock, 2004; Provan & Kennis, 2008; Provan, Fish & Sydow, 2007; Raab & Kenis 2009; Knight, 2002; Knight & Pye, 2005), this study is informed by the principal social theory of morphogenesis (Buckely, 1967; Archer, 2003; 2010; 2013), which developed from critical realism. Buckley (1967) first described morphogenesis as processes in a complex system that elaborates system form

or organizational state. In search of greater methodological clarity, and in critical response to structuration theory of Anthony Giddens (1979, 1984) and Pierre Bourdieu (1985), Archer expanded on Buckley's ideas by distinguishing the causal powers of structures and agents as interdependent mechanisms of transformation (Archer, 2003, 2010, 2013; Parker, 2000; Vandenberghe, 2005). She describes transformation as a morphogenic process that manifests in iterative system elaborations (Archer, 1996, 2003, 2010, 2013). Morphogenesis is culturally and historically situated following a path in which system regression and transformation are both possible (Lopez & Potter, 2005). Depth of context and intricate process tracing are required to explain the transformation brought about through structural elaboration (Archer, 2010).

Relational emergence theory is of the same critical realist tradition as morphogenesis. It adds explanatory power to the emergent properties of a whole network made possible by the particular social-interactional arrangement of its member parts. Such emergent properties afford the network causal powers that can affect change (Elder-Vass, 2010, 2014). Relational emergence theory describes two "critical moments" that characterize causation in change processes. First is the "structural moment" where institutional norms, and norm supporting behaviors, dominate and systems may tend toward stability or stagnation. Second is the "agentic moment" where social interactions – such as co-learning or development of shared meanings and histories – support non-normative behaviors and give way to emergent change altering the structures and creating a new context in which new norms develop. This iterative process of structural elaboration transforms systems over time through "morphogenic cycles" and is illustrated and described in more detail in Chapter Two (Figure 2.1).

The influence of Archer and Elder-Vass are apparent throughout this dissertation. Their theories – insistent on attention to history and context, the details of social configurations, and the non-linear nature of transformative processes – have expanded my thinking as a scholar and practitioner. An ambition of this dissertation is to serve as an exemplar giving these dense social theories purchase in an applied research context.

The organizational processual philosophy of Robert Chia (1999) uses the rhizome (see Deleuze & Guattari, *A Thousand Plateaus,* 1987) and is a critical layer of the

interpretive lens used throughout this dissertation. The rhizome is a decentralized multiplicity, a heterogeneous network with no beginning and no end where change is the norm and organization is the exception. Chia (1999; 2014) views change as constant and, like a rhizome, hidden from easy observation occurring beyond our managed control. He challenges the notion that organizations, through specific action, can cause change. He instead asserts that organizations such as networks are not action oriented entities, but rather sets of processes that can work intentionally to arrest change enough for agents to act more thoughtfully and guide change in the desired direction (Chia, 1999, 2014; Tsoukas & Chia, 2002). This processual view emphasizes "non-heroic micro-practices" of systems level change, which I observe as cultivated and co-constructed through network interactions (detailed in Chapter 3).

1.2.3 Landscapes of Practice

Learning in landscapes of practice theory (Wenger-Trayner, E. & Wenger-Trayner, B., 2015) also influences the study lens. Landscapes provides productive framing for understanding the experiences of network members, and how they interact, generating emergent properties that are more than the sum of individual actions. As the most recent iteration on communities of practice theory (Lave & Wenger, 1991; Wenger, 1998; Wenger 2000; Wenger, McDermott & Snyder, 2002), landscapes moves away from the community of practice as the locus of learning to focus on how individuals traverse a landscape of many communities and the boundaries between them (Wegner-Trayner, E. & Wenger-Trayner, B., 2015).

Landscapes can be considered on both network and individual scales. The framing accounts for the diversity of practices within a community and across a complex landscape of many communities. Primary to the concept is knowledgeability, the embodiment of knowledge gained by traversing one's landscape, which participants bring from across boundaries into the network nurturing learning and innovation. Landscapes also credits heterogeneity as a characteristic that adds richness to a community, in this case a network, as a collective and learning organization.

1.2.4 Transformative Learning Networks

This dissertation, in particular Chapters Two and Three, is part of the growing body of literature on transformative learning networks (Butler & Goldstein, 2010; Goldstein, 2010; Goldstein & Butler, 2010, 2009). Early parts of this study leverages NABI as a case in a comparative study presented in a conference presentation, a white paper, and a refereed article (Goldstein, Chase, Frankel-Goldwater, Osborn-Gowey, Risien & Schweizer, 2017a, 2017b). These collaborations position this study as a bridge between understanding the design, role, and potential of learning networks across social-ecological *and* social-educational systems. Investigations across sectors provide a richer contribution to contemporary understanding of the interface of science and society and opens the door for future learning across these domains.

Specific tenants from the literature on learning networks that tuned my lens includes concepts of triple loop learning (Argyris & Schön, 1992) and its counterpart in learning organizations (Senge, 1990). Also, ideas about social imaginaries (Anderson, 1983) describing "a dispersed collective expectation of how things work now, how they are supposed to work and how to engage with others to make them work that way" (Taylor, 2004). Such expectations provide individuals with a sense that they share in the life of a community, reinforcing solidarity within a group with common struggles and pleasures, despite the absence of personal relationships among all members of the group (Goldstein & Butler, 2009).

Learning networks are a specific type of loose network with geographically distributed members and member organizations. They are oriented around systems-level transformation when both top-down and bottom-up processes have failed to shift systems into desired change. I place these networks in context as one of many types of networks that have emerged over the last decades as alternative processes to solve society's intractable problems. I also contextualize learning networks in the broader interdisciplinary literatures. A few salient examples include Castells (1996), who described the rise of the network society and increasing importance of emergent networks in meeting societal challenges. More recently, Raab and Kenis (2009) describe a shift into a "society of networks" where the

dominant collective social entities are groups of individuals and organizations intentionally organized around making change happen. Weber and Khademian, with a collaborative governance lens, capture the fluidity and complexity of networks describing them as, "the enduring exchange of relations established between organizations, individuals, and groups" (2008a, p. 334). Networks are described as a promising approach to connect stakeholders across sites facilitating actors to "co-create solutions to shared problems through collaborative processes that lead to continuous improvement or perhaps even disruptive innovation" (Torfing, Sørensen & Røiseland, 2016, p. 19).

1.3 Methods

Methods focused on gathering empirical data to explain the case level processes towards transformative capacity. This included: 1) establishing pre-network conditions; 2) uncovering network practices that support learning across sites and scales; 3) identifying emergent properties likely to lead to systemic change; and 4) describing changes in systems and how they may, or may not, be related to the network.

Guided by participatory action research principles (Chevalier & Buckles, 2013; Baum, MacDougall & Smith, 2006; McIntyre, 2007) I take a qualitative single in-depth case study approach (George & Bennett, 2005; Goldstein & Butler, 2009, 2012) to detailing participant experiences in real time. Through collaborative design, frequent formative feedback and reflective practices, this approach actively informs the development and adaptive management of the network in question. In this way, the study embraces concepts of design-based implementation research (Penuel, Fishman, Cheng & Sabelli, 2011; Fishman, Penuel, Allen, & Cheng, 2013). This strategy attends to Wolcott's (1994) the three dimensions of qualitative research; that is description, analysis, and interpretation.

Participant observation and semi-structured interviews provided the most in-depth source of information (Bernard, 2011; Lofland et al., 1984; Weiss, 1995). This is because network participants are the best able to report and evaluate their lived experiences. Participant observation and interviews revealed unexpected, but significant elements of the network and most importantly are the source of empirically-based "thick description" (Geertz, 1994; Law, 2004) uncovering the system context, social interactions, emergent

properties, and processes that appear in the following chapters. The data was supplemented by a survey of network members (n=95), extensive document review, and review of member surveys conducted by NABI for the purposes of evaluation and understanding members and their institutional contexts.

Table 1.1 Data collected between April 2014 and April 2018

April 2014	Pre-research observations at NABI Summit
January 2015	Risien joined the Steering Committee and reviewed documents and meeting notes to date
April 2015	Observations: 2-day Steering Committee meeting; NABI Summit
May 2015	Interviews (n=2)
October 2015	Observations: Steering Committee meeting; interview (n=1)
April 2016	Observations: 2-day Steering Committee meeting; Advisory Board meeting; NABI Summit
September 2016	Observations: 2-day Steering Committee meeting; multiple meetings with non-members and NSF; interview (n=1)
December 2016	Interview (n=1)
March 2017	Analysis and report on listserv communications to date (485 messages); interview (n=1)
April 2017	Observations; 2-day Steering Committee meeting; Advisory Board meeting; NABI Summit; foundation partner meeting; interview (n=1); member survey (n=95)
May 2017	Observations 2 day NSF Convening on Broader Impacts; interviews (n=4)
June 2017	Interviews (n=5)
September 2017	Observations: 3-day Steering Committee meeting
Ongoing 2014-2018	Observations of monthly Steering Committee calls; review of relevant documents; review of listserv conversations; observation at broader impacts related meetings and review of communications from NSF.

Data interpretation centers on identifying key practices, experiences, emergent properties, and processes across sites and scales. The primary analytical activities included analytical annotations of field observations and application of open coding schemes to field notes, interview transcripts, and open-ended survey questions. This approach positions the researcher as the primary instrument with the role of tuning and applying a robust conceptual

frame and set of theories as a lens to guide interpretation of data collected while embedded in the network (Emerson, Fretz & Shaw, 1995; Lofland et al., 1984; Weiss, 1995). Analytic memos and field notes assisted in organizing an open coding scheme applied to the data guided by methods established for the development of grounded theory (Auberbach & Silverstein, 2003; Bernard, 2011; Corbin & Strauss, 2014; Glaser & Strauss, 1967; Miles, Huberman & Saldana, 2014) with an emphasis on emergent themes and intention to allow indefinite realities to surface (Law, 2004). All data described above was subject to open coding processes and subsets of data were also subject to closed coding processes (Miles, Huberman & Saldana, 2014) as described in more detail in Chapter Three.

1.3.1 Case Selection

I selected the National Alliance for Broader Impacts (NABI) because it is a secure network with funding for network operations from 2014 well into 2019. The network was still in the design phase at the beginning of this study. An early focus of the Steering Committee was to build nimbleness into the network design so NABI could respond and adapt to learning from research, evaluation, and reflection. These explicit intensions of the leadership positioned NABI as a prime candidate for participatory action research. As a researcher, I was in search of real time observation to capture experiences as they happen and offer a rare point of view in contrast to the usual retrospective qualitative case studies (George & Bennett, 2005). This strategy is time intensive and requires the researcher be embedded as an ethnographer. Real time observations have the advantage of accuracy as they do not rely on memory of informants nor require the researcher to reconstruct complex contexts and histories (Maxwell, 2013). I could, as an active participant, deeply engage in the content and observe social dynamics and experiences mediated through the network. Interview protocols and survey design were responsive to information gained through participant observations (Given, 2008) enhancing the information they yielded and elucidating rich detail about participant perceptions, expectations, and actions.

I have been a member of this community since 2013. I was invited to participate as a NABI Steering Committee member and as a participatory researcher in early 2015. The NABI principals are committed partners in this study. They have provided explicit access to

closed-door sessions and observational access to all NABI communications and events. The NABI Steering Committee collaborated on research questions and highlighted this research in their annual reports to NSF demonstrating the potential of NABI to inform other NSF investments in network approaches to change. NABI has provided committed collaboration, open access, reflective engagement, and desire to adaptively manage the network.

1.4 The National Alliance for Broader Impacts

To address the increasing expectations of transparency related to public investments in research NSF instituted policies that require research proposals to articulate "Broader Impacts". This requires researchers to demonstrate societal benefit of their work and engage in activities so that benefits can be realized by society. Since 2012, NSF has taken significant steps to respond to an influential report on the merit review process (NSB, 2011) and the America COMPETES Reauthorization Act of 2010. Universities, where most of the publically funded research takes place, have found themselves ill-equipped to comprehensively address broader impacts requirements (MacFadden, 2009) and new emphasis has only challenged universities more. The path to success is stymied by systemic deficits such as lack of researcher training to address broader impacts, unsupportive reward structures, and challenges in establishing necessary partnerships in the context of stable disciplinary silos (Risien & Falk, 2013; Risien & Nilson, 2018a, 2017b).

In 2013 a small collaborative campus based practitioners organized a Broader Impacts Summit, that served as the forerunner to NABI. Their goal was to innovate and build capacity for their institutions to develop and apply scalable solutions to broader impacts challenges. NABI now hosts an annual Summit, which is the critical social learning and community building event for the network and supporting transdisciplinary and inter-institutional collaboration. In 2014 the group received an award from NSF to establish themselves as a Research Coordination Network (RCN) grant (*MCB #1408736*). NABI aims to create and support a community of broader impacts professionals that can navigate the boundaries within, and across, institutions and between science and society.

1.4.1 Network Approach to Change

NABI aims to build individual capacity by fostering conditions for social learning and innovation. The network members cultivates a set of practices and create a new profession that navigates the boundaries within institutions by using the network structure to harness the energy and expertise of disconnected individuals working towards better connecting research to society. The intent is that, through NABI, these boundary professionals expand their professional identities and access a support structure in which they can learn, innovate, cultivate agency, and build capacity towards creating change at their home institutions. The network also brings together its membership and partner organizations to work towards systemic change such as providing the guidance for improving practice at federal funding agencies to better support broader impacts policies and creating opportunities for researchers to get broader impacts training and other support they need to succeed. NABI operates as part of a complex system that links institutions and NSF mediating a dynamic flow of information and practice serving as the conduit across scales reciprocally informing practice (Figure 1.1).

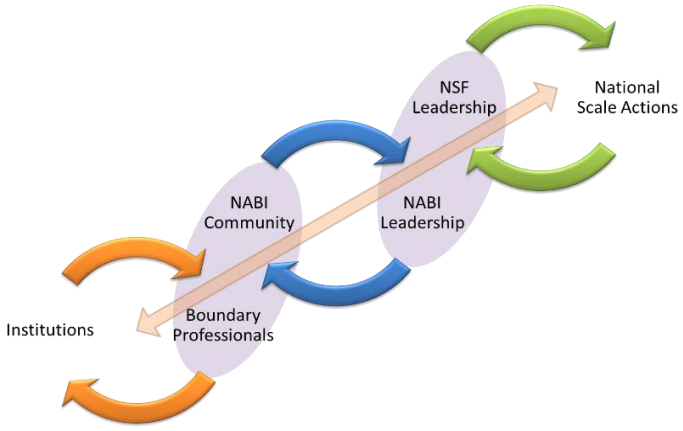


Figure 1.1. The role of NABI increasing the flow of information across scales.

1.4.2 Network Structure

The NABI structure is best described as a loose and complex web of connections and relationships with a variety of activity hubs. At the time of defense, the membership was approaching 700 self-selected individuals with varying degrees of engagement. An annual conference style Summit is the group's central event designed to encourage connection and learning supported and sustained between Summits by an active listserv. Activity hubs include: 1) the principal along with a small logistical staff based at University of Missouri; 2)

a steering committee that acts to some degree as a congress of members and drives the strategic direction, collective actions, and reflective and adaptive processes of the network; 3) an advisory board works to keep the network broadly relevant; and 4) subcommittees tackle specific needs such as financial planning, event planning, cyberinfrastructure, and training. Some members participate in the network and simultaneously represent complementary professional organizations, funding agencies, and university consortiums. This structure is intended to support broad-scale collaboration towards systemic change.

A more detailed description of NABI appears as a chapter in *Transformative Learning Networks: Guidelines and Insights for Netweavers* (Goldstein et al., 2017b). Cross-network analysis that includes NABI as one of four cases can be found in "Transforming with a Soft Touch: Comparing Four Learning Networks" (Goldstein et al, 2017a).

1.5 Theory, Practice, and a Path Forward

The next three chapters each stand alone as individual manuscripts and therefore contain overlap in theory, framing, and methods. There are also shifts in style; for example, Chapter Two and Four are written in first person and Chapter Three in third person in accordance with journal guidelines. Nevertheless these chapters work together to hone study of transformative learning networks with specific attention to boundaries and boundary work. They offer new meso-theory, detailed descriptions of structural configurations and variety of critical practices, and develop a concept of impact identities as a way of defining a research path that aims to strengthening the interface of science and society.

Chapter Two, "Boundaries Crossed and Boundaries Made: The Productive Tension between Learning and Influence in Transformative Networks", is framed using boundary concepts from across disciplines including science studies, social learning theory, and collaborative planning. The article presents learning networks as a promising collaborative approach to promote transformation across sites and scales and links these networks to ideas from general systems theory by applying a morphogenic lens to understand social-interactional processes that develop the transformative potential of learning networks. Co-author Bruce Evan Goldstein and I conclude that two types of boundary work - building boundaries and navigating across boundaries - operate in productive tension to respectively

expand knowledge resources and increase network authority and influence. Our work suggests that network practitioners can dynamically manage boundaries, shifting emphasis between strength and fluidity, to support change across sites and scales.

Chapter Three, "Experts and Sojourners in Learning Networks: Practices for Transformation", uses the detail of the case study to illustrate network complexities. The chapter describes network substructures that, together with a broad set of practices, enable multi-site multi-scalar transformation. Drawing on literature in public administration and collaborative governance, the article builds on the meso-theory of productive tension in Chapter Two by examining complexity of network substructures, roles, and practices. The article offers a typology, along with empirical detail and interpretive explanation, of the many practices of *experts* and *sojourners* in the system. By providing detail and context beyond a simple set of best practices, the article reveals specific processes that work in concert to create transformative capacity. The primary claim is that multiple structures, and a variety of expert and sojourner actions, are interdependent and contribute to the transformative potential of learning networks. I encourage network leaders to avoid prioritizing specific structures, roles, or practices in the system. Instead, network designers and leaders should embrace complexity reminded that a variety of planned and emergent structures and practices all have a role to play in strengthening the transformative capacity of a learning network.

Chapter Four, "Unveiling Impact Identities: A Path for Connecting Science and Society", is written in collaboration with Martin Storksdieck and addresses the changing landscape at the interface of science and society in the context of recent efforts, including NABI, to improve connections between scientists and the public. The article uses framing about boundaries and identity summarized above. It is deeply informed by, but not a direct analysis of, the NABI case study. The concept of impact identities, scientists' self-concept around broader impacts, is one that emerged in my own site-based work. The ideas were shared and enhanced through interactions with the network, and have now proliferated through the network. Working with scientists on integrating broader impacts with their personal and professional identities has developed in NABI as one promising path to

addressing the culture change necessary to support non-normative behaviors and ultimately morphogenesis. This is all in service of the desire to better integrate the spheres of science with society in support of mutually beneficial communication and learning.

The impact identity concept draws attention to an important system condition that constrains transformative potential of NABI and other collaborative efforts emerging in science society interface. Chapter Four sets the foundation for the next steps in my own inquiry understanding the specific constraints in the systems and investigating possible solutions through design-based approaches. It appears that integrated identity development may be an essential ingredient and this spurs future research questions. How can site-based actors support scientists in expanding their professional identities to include their role in realizing societal impacts? How does expanded identity alter scientists' broader impact practices? How are ideas about impact identity cultivated in, and propagated through, the network by both experts and sojourners?

In the article we lay out the foundation for future design-based research by proposing a thoughtful process for scientists to develop their "impact identity", a concept that integrates scholarship in a scientific discipline with societal need, personal preferences, capacities and skills, and one's institutional context. We hypothesize that well-developed impact identities foster systematic approaches to broader impacts that will result in better outcomes for scientists and for society. Widespread adoption of the concept of impact identity may have implications for the recruitment and retention of a more diverse range of scientist. It is also likely to improve the reach and effectiveness of professional support systems, such as NABI, that work to better connect science and society.

Chapter Five concludes the dissertation with a synthesis of key findings and implications as well as future directions of research in two areas 1) transformative learning networks, and 2) mechanisms that disrupt systems and increases the flow of information and interaction between scientists and other sectors of society.

2 BOUNDARIES CROSSED AND BOUNDARIES MADE: THE PRODUCTIVE TENSION BETWEEN LEARNING AND INFLUENCE IN TRANSFORMATIVE NETWORKS

Complexity is a pervasive challenge of systemic social, environmental, and educational change efforts. Zellner and Campbell (2015, p. 458) view complexity as "both the source of intractable wicked problems and a way to trace the pathway out". While our societal solutions once emerged from traditional organizations (Perrow, 1991), new approaches have evolved as complexity of our social systems increases. Castells (1996) described the rise of the network society and increasing importance of emergent networks in meeting societal challenges. More recently, Raab and Kenis (2009) describe a shift into a "society of networks" where the dominant collective social entities are groups of individuals and organizations intentionally arranged around making change happen (Raab & Kenis, 2009). Foundations and large-scale organizations and agencies are heavily investing in networked approaches to systemic change and embracing the lens of complex systems.

Most public sector network designs center on a core structure of connection across organizations with an emphasis on social interaction. There are many different options depending on the challenge at hand. Networks may emphasize collective impacts, generative social-impacts, collaborative regional civic outcomes, governance, or other priorities (Considine, 2013; Innes & Rongerude, 2013; Kania & Kramer, 2011; Plastrik, Taylor & Cleveland, 2014). Our focus is on transformative learning networks, which are multi-sited, multi-scalar, voluntary collaboratives that nurture professional learning and expertise in fields such as environmental management, public health, and education (Butler & Goldstein, 2010; Dolle, Gomez, Russell & Bryk 2013. Goldstein & Butler 2010). Learning networks enhance transformative capacity by promoting a common professional identity among members, and by guiding them to a shared understanding of how they can bring about transformative change (Goldstein, Chase, Frankel-Goldwater, Osborn-Gowey, Risien, & Schweizer, 2017a; 2017b; Goldstein & Butler 2010; Goldstein & Butler 2009). We aim to

show how a learning network can progressively build such transformative capacity inclusive of both innovations of practice and influence on policy. We claim that understanding social-interactional processes over time, such as boundary work, is essential to guide more adaptive network design and facilitation. Our analysis explains on how different types of boundary work can contribute to network-mediated transformation of complex social systems.

We combine ideas about boundaries and boundary work with the theory of morphogenesis (Archer 2003, 2010, 2013; Buckley, 1967), which enables us to identify social-interactional processes of transformation. We explore boundary work, both building and navigating boundaries, as a set of such processes. Our thesis is that these two types of boundary work are interdependent, and that engaging in both promotes transformative capacity of a learning network. We agree that transformative capacity is the result of structure working on agents and agents working on structures (Giddens, 1979, 1984). We also concur that analytical disentanglement of structures and agents is necessary to develop theory about how interactional processes enable transformative capacity over time (Archer, 2010). We see these two types of boundary work in a productive dialectic tension (De Cock & Sharp, 2017; Seo & Creed, 2002). Boundaries developed around network membership and ideas support network claims of authority. Boundaries navigated, across the many communities in a complex landscape, expand learning and innovative potential among individuals, organizations, and across disciplines.

We contribute an empirically grounded meso-theory that expands morphogenesis (Archer, 2003, 2010, 2013) making the perspective accessible to learning networks working towards transformation across scales and sites. We provide examples of the boundary work that network actors conduct on the path to transformation. Our purpose is to support the work of two types of network actors engaged in such transformative processes. First, network members that serve in a *sojourner* role and focus on site-based work to shift everyday norms, demonstrating a keen awareness of how institutions enable and constrain their efforts. Second, network leaders that serve in an *expert* role, designing networks to provide meaningful member engagement opportunities across sites and at the same time building identity and coherence to enable transformation at multiple scales. These expert and

sojourner roles are interdependent and generally correspond with boundary building and boundary navigation respectively.

Three sources are influential in our theory. First, we draw on different disciplinary ideas about boundaries. These include Gieryn's (1995, 1999) syntheses of boundaries and boundary work that pull together insights from science studies, social worlds theory, and organizational studies; and Lamont and Molnár's (2002) review of boundary studies across the social sciences. We also apply more recent theory emphasizing the learning and collaborative opportunities accessed by actors as they traverse boundaries (Engeström, 2009; Wenger-Trayner, E. & Wenger-Trayner, B., 2015). Second, we draw from general systems theory about systemic change through morphogenesis defined by Buckley (1967) and developed by Archer (2003, 2010, 2013). Third, this framework is informed by the interaction between the theories above and field observations of emergence, structures, learning, and practices in several transformative learning networks (Goldstein & Butler, 2009, 2010; Goldstein, 2010; Goldstein et al. 2017a, 2017b).

In this next section, we summarize current understanding of boundaries and boundary work, the morphogenic processes of systems transformation, and transformative learning networks. We follow with a network case study that traces how transformative potential can result from dynamic and productive tension between two types of boundary work.

2.1 Boundaries and boundary work

Understanding boundaries from both structural and social-interactional standpoints is integral to understanding change in complex systems. In this section, we highlight salient literature to guide conceptualization of boundaries as structures in the system and introduce two types of socially negotiated boundary work. We assert that boundaries are socially constructed and manifest in a variety of structural configurations. They are multilateral and multidirectional, crossing geographies, institution types, disciplines, professional roles, and power structures. We observe boundary structures as intricate, reflecting the complexity of social systems undergoing transformation. They serve to demarcate one group of actors and set of practices from another, bolstering group claims of authority, enabling shared understanding and language, and lowering barriers to in-group collaboration. Concurrently,

boundaries serve as dynamic and shifting spaces in transforming social systems where there is enhanced opportunity for interactions that result in intersectional learning, innovation, and emergent change.

Boundary work occurs at the intersections of social worlds (Star & Griesemer, 1989) or in the spaces between bounded communities (Wenger-Trayner, E. & Wenger-Trayner, B. 2015). Such work was originally described by Gieryn (1983, 1999) in terms of demarcation, where the stronger and more impermeable the boundaries the better one group could be distinguished from another. Boundary-work was articulated as "strategic practical action" (1983, p. 23) strengthening and maintaining boundaries that separate distinct groups. Abbott (1988) emphasized how strong professional boundaries support jurisdictional authority in professional settings. Others consider boundary work not in terms of demarcation, but more in terms of socially mediated learning and collaboration that occurs across boundaries. Engeström (2009) describes such work as "opening the dimension of horizontal socio-spatial interactions" (p. 68) and joint activity that occurs across boundaries as a "socio-spatial expansion" (p. 77). Wenger-Trayner, E. and Wenger-Trayner, B. (2015) describe boundaries as "learning assets" or places in a landscape of practice where the knowledge resources from a multiplicity of other communities of practice converge "rich with new insights, radical innovation, and great progress" (p. 17).

Boundary structures exist with varying degrees of permeability that enable or constrain social interactions that contribute to transformation. When boundaries are too formal and impermeable they contribute to system rigidity and routinization of practices, which causes isolation and stifles innovation and learning (Abbott, 1988; Gieryn, 1995; Seo & Creed, 2002). On the other hand, more permeable boundaries can challenge and break apart strong social norms (Abbott, 1995; Lamont & Molnár, 2002)[1]. Building strong boundaries develops expertise and authority of a group (Abbott, 1995; Gieryn, 1983). Navigating across boundaries cultivates broad knowledgeability and potential for cooperative

[1] Permeability is used here similarly to how Lamont and Molnár (2002) describe symbolic boundaries as "conceptual distinctions" (p. 168) over which actors and groups struggle and converge; and aligned with how Abbott (1995) describes proto-boundaries as unstable and dynamic boundaries that can eventually give rise to new social entities.

collective pursuits accomplished at the intersections of social worlds (Star & Griesemer, 1989).

Gieryn's (1983) understanding of boundaries as fluid, socially constructed, and continually reconstructed over time highlights the dynamic nature of boundaries. Such fluidity aligns with the idea that boundaries can give rise to new social entities, such as networks, as actors cross boundaries to come together around points of difference (Abbott, 1995). Transformative learning networks emerge in the space between established boundaries as actors identify points of difference with their dominant disciplinary or professional communities and find alignment with actors across boundaries in other communities. The multiplex nature of boundaries – multilateral spanning across organizations, sectors, disciplines, and professional positions (Weber & Khademian, 2008b) – is a defining characteristic of these systems in which learning networks disrupt the status quo by facilitating new processes and relationships. Boundaries between sites are not just geographic, they also demarcate differences in institutional focus, culture, size, power structures, values, and norms of practices. Network members are also dealing with boundaries between the many professional disciplines and hierarchies of people who need to coordinate and collaborate in order to stimulate change.

Here we use the term *boundary work* specifically to include two types of work operating in productive tension in complex social systems and applied to learning networks. *Boundary navigation* practices include members noticing common practices, challenges, or goals across boundaries *and* taking steps to connect across boundaries to learn. This work extends to actors applying and adapting newly gathered knowledge, and aligning new practices and perspectives with other communities in their landscape of practice. Having expanded their knowledgeability members can express and share it with the network community (Wenger-Trayner, E. & Wenger-Trayner, B., 2015). Networks bring actors together, reducing barriers to learning and grow the knowledge resources of the collective. Networks also work to build capacity for the considerable skills this type of boundary work entails (Kubiak et al., 2015). *Boundary building* includes efforts by network leaders and members to collectively cultivate a shared identity, history, and language and demarcate

themselves from others (Gieryn, 1983) as practitioners in a domain (Wenger, 1998). A critical outcome of boundary building is professionalization of the role of network members in an emerging field. Network authority and influence in the system develops as outsiders recognize the expertise of the network. Members can in turn leverage the network to gain recognition and authority at their sites for their practice.

2.2 Morphogenic process of transformation

We take a view of *transformation* that is processual, rarely with an identifiable beginning or end. Where, "the present is not merely the linear successor of the past but a novel outcome of it" and each moment "absorbs the preceding one, transforming it and with it the whole, constituting at each stage of the process a novel and never-to-be-repeated occasion necessarily grounded in its past, but always projected towards a not-yet knowable future (Chia, 1999, p. 220). Transformation is not merely the result of structures or agents of managed change, but of synergistic effects of many small and unrecognized acts that together stimulate change (Chia, 1999, 2014; Tsoukas & Chia, 2002). Complex systems undergoing transformation are in continuous states of emergence and are "above all the product of coupled, context dependent interactions" (Holland, 2000, p. 121).

To account for the complexity we must consider both structure and agency as having causal powers in transformational processes. We understand structures as objectively determined and capable of supporting or impeding action (Merton, 1968). Agency, on the other hand, is subjectively determined and understood as the capacity of individuals to make choices and to act on behalf of, or against, themselves or a collective (Bandura, 1986). The specific relational arrangements in a system can enable or constrain change (Elder-Vass 2010, 2014).

To examine the role of boundary work and its contribution to transformative capacity of learning networks, we must understand transformation as an intricate process. Critical realism offer useful poststructuralist methodological options for examining transformation as a process that can be traced (Archer, 2010, 2013) and assigns causal powers to both structures and agents in the system (Elder-Vass, 2010). Buckley (1967) first described morphogenesis as processes in a complex system that elaborates system form or

organizational state. In search of greater methodological clarity, Archer (2010, 2013) expanded on Buckley's ideas as she critiqued Giddens' accounts of change as mutually constituted by structures and agents (Bourdieu, 1985; Giddens, 1984). Archer claims the structurationists confound the differences between structure and agency, making them analytically indistinguishable and robbing social scientists of opportunity to identity causal mechanisms in the system (Archer, 2003; Parker, 2000; Vandenberghe, 2005). In Archer's dualist account of morphogenesis, transformation of structures and agents is interdependent, occurs through social interaction including the social construction of knowledge, and manifests in iterative system elaborations (Archer, 1996, 2003, 2010, 2013). Morphogenesis is culturally and historically situated following a path in which system regression and transformation are both possible (Lopez & Potter, 2005) and a depth of context and intricate tracing of process is required to explain structural elaboration (Archer, 2010).

Structural elaboration is the result of morphogenic process and is not replacement of one state with a new state. Elaboration instead indicates a system with a "host of new social possibilities, some of which will come into play gradually" (Archer, 2010, p. 241). Time is critical in analysis of morphogenic cycles. Archer predicates her theory on structure logically predating action, action predating elaboration, and elaboration reinventing structure, thus beginning a new morphogenic cycle with new conditions. In each subsequent cycle "subjects are re-centered and structures are re-installed" (Parker, 2000, p. 84). New conditions created by the previous elaboration are manifest in each cycle, but inherit the full context of the system history. In the progression, new conditions enable new types of social interactions. Agents have causal powers through interaction and are themselves changed by elaboration.

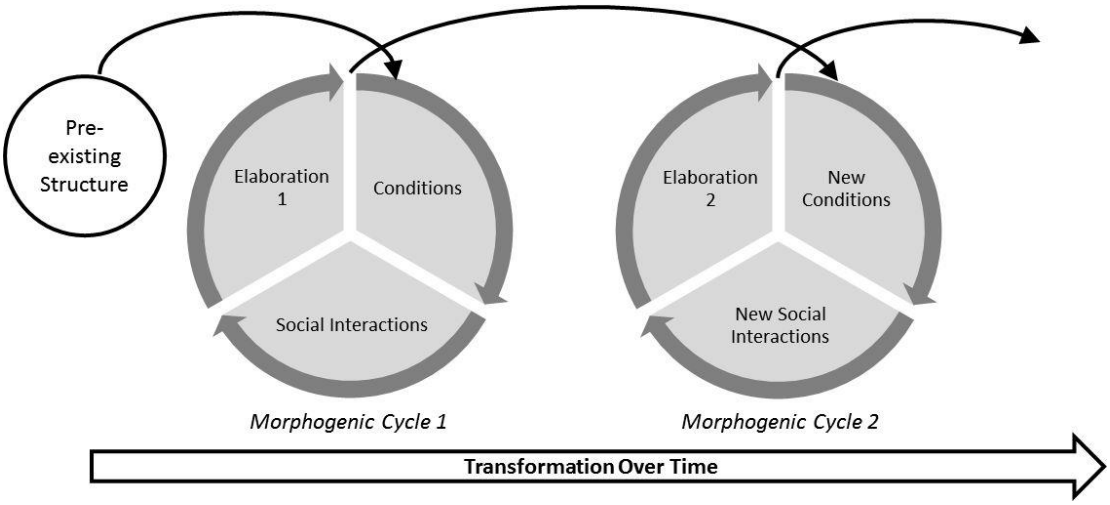


Figure 2.1. Progressive morphogenic cycles.

Building on Archer's diagram of morphogenesis (2010, p. 238), we offer Figure 2.1 to disentangle the stages, or "moments", in each morphogenic cycle. The social-interactional moment is our primary concern as it serves a causal role, stimulating the process of morphogenesis in the system (Elder-Vass, 2010, 2014) and we explain it here as manifest through boundary work.

2.3 Transformative learning networks

Transformative learning networks are voluntary collaboratives that nurture professional learning and expertise in fields such as environmental management, public health, and education (Dolle et al., 2013; Goldstein & Butler 2010a). These networks maintain a loose and light structure (Goldstein et al. 2017a) and amplify opportunity for transformative change by integrating diverse site-based priorities and innovations with facilitated community-wide interactions and learning (Butler & Goldstein, 2010; Goldstein, 2012; Goldstein & Butler, 2009, 2010; Goldstein et al., 2017b). These learning networks "are attempted when deeply rooted obstacles to institutional change have proven resistant to both top-down or bottom-up change strategies" (Goldstein et al., 2017a, p. 4).

Recent work examining learning network facilitation practices, organizational learning, and transformative capacities in four learning networks provides insights into the important role of boundary work (Goldstein et al., 2017a, 2017b). Key actors navigate boundaries by circulating ideas and practices between network sites. Regular whole-network gatherings enable social learning among members who have different ways of knowing, social roles, training, and experience. Network leaders cultivate interaction that contributes to network-wide shared identity, language, and professional practice. Achieving coherence without overt coordination, networks can have an emergent impact on higher-scale properties like federal policy.

As this implies, transformative capacity is more than the sum of individual network members activities, but emerges from a productive tension of weaving together multiple perspectives and experiences into shared understanding, without collapsing into a single point of view or set of practices (Goldstein et al. 2017b). Network leaders serve to mediate the relationship between heterogeneous sites and the collective whole, supporting expression and adoption of new professional identities that can promote higher-order coherence while also enabling preservation of site autonomy.

In contrast, transformative potential is less apparent when networks prescribe a specific approach to professional practice or have a relatively rigid organizing structure. For example, Chase and Frankel-Goldwater found that prescribing lines of communication exacerbated conflict between local and network-wide identity and objectives (Goldstein et al., 2017a). Networks with more fluid boundary practices were more capable of facilitating information flow, forging social ties, engaging in collaborative learning, and promoting a shared professional identity (Goldstein et al., 2017b). This recent work broadly informs the the meso-theory developed here.

2.4 Methods

We ground and refine our meso-theory of productive tension of critical boundary work through inductive qualitative analysis of a single in-depth case study (George & Bennett, 2005). We take a processual approach narrating and sequencing emergent activities and properties to understand the patterns of the collective (Van de Ven & Poole, 2005)

Embedded as a participatory researcher from April of 2014 when the network was established, the lead author ethnographically captured the progression of boundary work of the National Alliance for Broader Impacts (NABI) through April of 2018.

Data collection was multifaceted, which ultimately enabled the development of process theory (Van de Ven & Poole, 2005). It included participant observation of frequent network leadership calls, biennial multi-day steering committee meetings, advisory board meetings, and annual full network gatherings. Observations were also conducted during meetings with NSF staff and private foundations interested in supporting and adding energy to the transformation NABI seeks. Additional in-depth data came from semi-structured interviews (n=18) which focused on understanding the everyday work and professional identities of network members. An online survey to participants of the 2017 annual network gathering (n=95) also contributed some open ended responses about how members see the role of the network and themselves in it. Initial analysis used emergent open coding procedures (Miles, Huberman, & Saldana, 2014) to categorize all field notes, transcripts, and open-ended survey responses resulting in 460 substantive excerpts broadly having to do with boundaries and boundary work. These excerpts were subjected to second round of open coding during which we parsed them into structural and agentic aspects while also identifying types of boundaries and types of boundary work. Excerpts were then sequenced and further evaluated through process tracing using the morphogenic lens and focusing on change over time. Process tracing involved searching the boundary work excerpts and making informed causal inferences linking boundary work in temporal sequence to intermediate network outcomes. This type of process tracing is aimed at building a plausible generalizable middle theory of causal mechanisms based on richness of evidence in a single case (Beach & Pedersen, 2013).

There is an inherent paradox in disentangling features of a complex system to explain how they relate to one another. We recognize the risk of a reductionism that would discount the very complexity so central to our lens, and we identified some unavoidable issues. For instance, while we attempted to maintain a coherent and progressive sense of time and process, we realize that the assignment of a specific moment to system elaboration helps with

descriptive clarity, but if ultimately subjective. The aspects of the system we examined and our understanding of pre-existing conditions deeply influenced our detection of shifts from one morphogenic stage or cycle to the next (Archer, 2003, 2010). One may reanalyze the system to examine different phenomena and the results would likely identify different punctuating moments of elaboration. This is acceptable because the we aim to capture processes and interdependent actions and conditions as the system is emerging and elaborating; the specific moment a system moves from one subjective state to the next is inconsequential. We acknowledge our lens of boundary work directly influenced our analytical choices and interpretation of viable causal inferences.

2.5 Case study: the National Alliance for Broader Impacts

The NSF has explicitly required research proposals to articulate 'broader impacts' or the societal benefits of research since 1997 (NSF, 2014). The *America COMPETES* reauthorizations of 2010 and 2015, a report from the National Science Board in 2011, and the *American Innovation and Competitiveness Act* (passed in December, 2016) have all reaffirmed the importance of broader impacts work. Universities have found themselves ill-equipped to address these requirements because of a lack of researcher training to address broader impacts, unsupportive reward structures, and challenges in establishing necessary partnerships across disciplines and organizations (Risien, 2017; Risien & Falk 2013). The NSF has taken concrete steps to improve processes to better support broader impacts, but change has been slow. The agency relies on the research community to shift how they value, review, and practice broader impacts. Conversely, the research community looks to the agency for direction (NABI, 2018). In 2013 several university faculty, outreach professionals, and administrators came together in the first Broader Impacts Summit, which led to NABI. The network, supported by a 2014 NSF award, aims to foster development of sustainable and scalable institutional capacity to support broader impacts. NABI seeks to build individual capacity by cultivating a set of shared practices and a supportive community for members to build capacity for broader impacts in their home institutions. The network has more than 600 members participating with various levels of engagement. Annual Summits are the network's main venue for fostering connections between members. Between

Summits, members maintain learning and exchanges on the NABI listserv and through other individual and small group interactions. One network member describes the draw of the network, “I think there are the two things: it’s the very deep and meaningful tie to the agencies and structures for decision-making; and the very deep and meaningful tie to the communities that are doing this work, [NABI is] a kind of go-to for those” (interview, June 2017).

2.5.1 Boundary navigation and expansion of knowledge

Site-based professionals working to support scientists in developing better broader impacts practices were responsible for the creation of NABI. One such professional describes initial efforts in simple terms, “I was struggling with this, and I was alone on my campus, I thought others must be struggling too, so I invited people to talk about it” (interview, Oct 2015). That first step of bringing people with shared challenges together was critical for practitioners in establishing a mechanism for dispersed professionals to come together around similar experiences of embedded institutional conditions and social norms impeding progress on broader impacts. They were all grappling with similar issues such as the disconnect between academic reward structures and quality broader impacts work. They shared their frustrations with the way many scientists placed low value on broader impacts work relative to disciplinary research. Broader impacts support was, at that time, only recognized as a professional activity on a few campuses despite the fact that many had been performing the role. After the initial Summit, a small group submitted a proposal to NSF to form the network, and NSF began modest support for what one NSF staff member referred to as an “experiment [to] move the needle on broader impacts” (observation, April 2016). NABI leadership introduced a regular rhythm of facilitated networking opportunities for university-based broader impacts professionals through the annual Summits and listserv.

At the summits and on the listserv, NABI members engage with peers from other institutions. They share tools and ideas, discuss their experiences experimenting with new approaches, and showcase progress and activities on their campuses. Sophistication of presented institutional models and guidelines for practice increased over time. Leadership in NABI provides ample open and unstructured time to promote deeper connection between

members and encourage them to share challenges as well as successes. Early in the network, the leadership often reminded members that everyone was learning together, since "nobody is an expert here" (observation, April 2015).

NABI also enabled members to regularly access influencers at the national scale, such as representatives of university associations and NSF personnel who shared the network goal of advancing broader impacts practices. This influence deepened as veteran network participants began to recognize their own expertise. Over time other universities, organizations and NSF sought out network experts for their knowledge and ability to tap into the collective knowledge of the network.

A year and half after NABI began, one network leader shared in a steering committee meeting that an early goal was to refine and then propagate an institutional model that was working well at one university. The expectation shifted over the first two years of the network; leadership was embracing experimentation at each institution, encouraging members to evolve models that made sense for their institutional structures and cultures. During early observations, members acknowledged that while they participate in NABI with the intention of learning collaboratively, their institutions were also in competition with one another to use improved broader impacts to grow their institution's research enterprises. Initially, in this context of competition, we observed members as reluctant to share tools and resources that they had created for their own campuses. Over the course of time, we observed members opening up and sharing more resources with colleagues through the network and helping each other through the listserv. Interviewed members also reported collaborating on and sharing resources in pairs between network gatherings.

Although the NABI leadership explicitly avoided prescribing specific institutional models for addressing broader impacts, best practices did emerge through network communicative processes. A group of members worked through the network to create a synthesis of such practices and published a guiding principles document (NABI, 2016). This document served as a reflection of core practices exposed, tested, and in some cases innovated through interactions facilitated by the network. Members use the guiding principles document to anchor consultations with scientists developing broader impacts and

to engage administrators who are in a position to support members' broader impacts roles. Some NSF programs also use the document to orient review panels to principles they may use in their review of broader impacts aspects of proposals.

As NABI members developed knowledge and experience, they began to request opportunities for more advanced learning at network gatherings. They also requested additional formalized knowledge products like the guiding principles document to support their site-based work. As seasoned members sought opportunities for more specialized learning they also began to identify themselves as broader impacts innovators central to the development of the profession. The broader impacts community had progressed from a group of unconnected, site-based non-experts to a network with a regular rhythm of opportunities for connection and learning. This network has similarities to a community of practice, with central members who are innovators and holders of what it means to be competent in the broader impacts domain, active members who are developing their expertise, and legitimate peripheral participants who access the knowledge of the domain as needed (Lave & Wenger, 1991; Wenger 1998). As the network developed collective knowledge and authority in the domain, new members continued to join and began their work from the position achieved by those already in the network. They experienced a lower barrier to entry and were more readily able to understand the challenges and promising practices around broader impacts.

Demand for broader impacts knowledge has increased as evidenced by both the growing number of NABI members, and members' reports that scientist are seeking their services more frequently than they can accommodate. As NABI has developed robust knowledge resources, more individuals and organizations not directly involved in the network seek out advice and products of the network. The broader impacts community is progressing and conditions appear to be changing as campus momentum and expectations around broader impacts is accelerating. The demand for access to network knowledge extends beyond those who are interested in themselves engaging in the network; many are simply looking for access to information about developed techniques for application. The NABI leadership has identified the next step in the evolution of the network. They have a

long-term plan to maintain the learning network and additionally build a resource center to serve the expanding needs of the community.

2.5.2 Boundary building and expansion of authority

Network authority in the broader impacts domain has grown as the network progresses. NABI Leaders use annual gatherings as an opportunity to facilitate deeper shared meaning, histories, language, and experiences of among active members. The gathering is the most critical part of the network effort to build boundaries and demarcate who is in the network and who is not, distinguishing the members as change agents in the domain. Participants report that NABI gatherings leave them energized and emboldened when they had previously felt alone in their efforts to promote broader impacts practice on their campus. One member exclaimed at the end of a gathering, "I've finally found my tribe!" (observation, April 2014), another referred to NABI shortly after attending a summit as "my affinity group, I've found my affinity group!" (interview, May 2015).

NABI leadership has maintained an ethos in these events of openness and sharing, and uses rhetoric of NABI as a family. The leadership intentionally boosts members' sense of shared identity as broader impacts professionals, "we are all in this together, we are all figuring this out together" (observation, April 2015). Network leaders tell the history of NABI at the beginning of each gathering bringing new members up to date and explicitly including them in the shared story of the network from that point forward. At the end of each gathering, leaders revisit the history and add a new chapter through group reflection on the learning and personal connection achieved during the gathering. During a town hall at the closing of each summit, NABI leaders issue a call to all members to reach out and contact any other member with any need. They empower members as broader impacts professionals with a right to claim expertise in the professional domain. For example, one leader acknowledged the growing expertise in the room by asking for a raise of hands on how many proposals members work on each year, "more than 20, more than 10…" The leader then asked the membership to remember that the scientists they support may only work on a few proposals per year, and "we are the ones with expertise on this" (observation, April 2015). In that same session, leadership pointed out the group's ability to take collective action, saying

"I'm not saying we should all become lobbyists, but…that's the power of us all in one network distributed all over the place… we need to engage our politicians… show them the good things that are happening in their districts" (observation, April 2015). Finally, attention to shared language has also been an important and ongoing discussion in the network – as one member put to the group, "What do *we* mean when we say 'broader impacts'" and, "the language we use is important". Another member responded that, "it's still not clear what NSF wants, what they mean by innovative approaches" to which network leaders responded that it is "up to us, if NSF doesn't know, then we have an opportunity here" (observation, April 2015).

Another regular activity that expands network authority is cross-site visits, in which a group of NABI members provide broader impacts trainings and meets with university administrators. Network leaders use these opportunities to inform administrators of the national momentum and evolving NSF policies on broader impacts. Some of these visits have influenced institutions to increase support or allocate new resources to broader impacts support. For example, one campus established a new campus-wide broader impacts initiative and hired a local active NABI member to direct it. Site-based members of who hosted NABI visitors report that visits stir university administrators' sense of competition with their aspirational peers, which encourages them to invest resources or better value of the work of broader impacts professionals. Members also report these visits provide them with enhanced access to campus administrators.

In 2017 there was a marked increase in incidences where program administrators and other people in positions of power engaged with NABI members to improve broader impacts practice on their campuses. For instance, an NSF Assistant Director, having recently returned to a university upper administration position, signed on to serve on the NABI advisory board. The NSF Director of the Office Integrative Affairs travelled from D.C. to the west coast to participate in the annual network gathering providing a keynote speech. NABI also garnered support from a private foundation interested in advancing broader impacts practice to convene university administrators, representatives from university associations and

foundations, exemplar scientists, and key NABI members and NSF staff in a two-day workshop to discuss national progress on improving broader impacts.

2.5.3 System elaboration

There are indicators that the network growth in terms of NABI's knowledge resources and claims to authority may be plateauing, which may indicate a system elaboration from one cycle and set of conditions to a qualitatively different set of conditions. New members are still joining the network to grow their own knowledge and authority. Some seasoned members have reported that what they have learned in the network has served their professional advancement; and now that they have established a durable and well-resourced broader impacts infrastructure at their sites, their needs are advancing.

The NABI leadership has taken notice that many members now need a different, more advanced sort of support and is taking measures to adapt their practice to meet the needs of those members. The 2018 Summit will include a research track to emphasize scholarship of broader impacts reflecting the focus of veteran members on developing scholarship in the domain in which they have already worked to advance practice. NABI has also engaged with organizations establishing broader impacts journals to ensure that the journals match the needs of NABI members and their collaborators. A subset of the NABI leadership recently proposed a 6.2 million dollar effort to NSF to develop extensive resources that support broad-scale improved broader impacts practice across the country. If funded the effort would provide direct resources for broader impacts to scientists and the professionals that support them. The resource center would indicate a new set of conditions enabling new social-interactions and practices.

Our analysis concentrates on morphogenesis as a process whereby the system progresses from cycle to cycle through boundary work. Table 2.1 describes system conditions prior of the creation of the network as cycle one and the current conditions as evidence of elaboration into cycle two. We posit possible future conditions of cycle three and have early evidence that indicate this is likely. This includes recent emphasis in the network on broader impacts scholarship and long term visioning for NABI to become a self-sustaining professional association. This analysis focuses on boundary work as a social-

interactional driver of system elaboration from cycle one to cycle two in terms of expansion of knowledge and authority.

Table 2.1. System conditions in each of three morphogenic cycles

	Cycle 1	Cycle 2	Cycle 3
Knowledge	no mechanism for social interaction	network facilitates regular social interactions	sustained social and a-social channels
	knowledge resources are limited and dispersed	expanded embodied knowledge and resources	knowledge base well established, scholarship emerges
	practices are unrefined or occur in isolation	best practices exposed, applied and openly available	best practices are normalized
Authority	isolated individuals working w/out authority	increased individual efficacy, bolstered by network	individuals identify as experts, profession is normalized
	institutions are unaware of challenges	institutions invest resources support practice	institutions infrastructure is normalized
	network emerges to define problems and domain	network influences some allocation of resources	network influence expands, becomes professional association

Boundary navigation began before, and contributed to, the creation of the network itself and centered on construction and flow of knowledge. As the network grows, boundary navigation activities expand knowledge resources. In morphogenesis, agents engage in boundary navigation to shift broader impacts practice by enriching the system with social interactions and opportunities for learning. As cycle one begins, the system is void of regular mechanisms for connection and social interaction between sites and between practitioners. Knowledge resources are limited and dispersed among disconnected practitioners and sites. Cycle one practices generally occur in isolation and under conditions that do not support sharing or collective refinement. In cycle two, the network facilitates a regular rhythm of opportunity for social interactions around broader impacts. The network cultivates individual and collective learning. As the system progresses to cycle two, best practices emerge based on repeated member experimentation across sites and communication through the network about successes and challenges. Network facilitation and structure enables and prioritizes open sharing of tools and principles to guide practice.

Boundary building increases the authority and influence of the network as a collective over time. This occurs across scale, from site-based influence leveraged by members to national influence leveraged by network leaders. Network agents engage in acts of boundary building, shifting conditions of authority and influence from one cycle to the next. In cycle one the broader impacts domain is not established, there are no legitimate claims of authority, and only a few campuses have invested resources into support broader impacts infrastructure. In cycle two, boundary building effects are most apparent for individuals who experience increased efficacy in their own work because of network interactions and are able to leverage the influence the network to garner local resources. In cycle three more collective effects become apparent as the field professionalizes and the new conditions support development of new and improved broader impacts norms of practice. Scientists have increased access to broader impacts support and increased understanding of how to include broader impacts practices and partnerships in their research.

2.5.4 Productive tension in the network

The two types of boundary work are dynamic in the system, pulling it in two directions concurrently. For example, in steering committee meetings the leadership extensively deliberated about appropriate network boundaries. They struggled to define who should be in the network and debated about the trade-offs and advantages of establishing such boundaries. Ultimately, they decided to maintain fluid boundaries even though it may have made developing shared language and identity more difficult. They spent significant effort on supporting shared identities, language, and histories among network members and explicitly demarcating the domain of broader impacts while explicitly maintaining open participation of agents. These examples capture the dialectic tension between the two types of boundary work and the ultimate progressive synthesis of the network that dynamically manages both. On the one side, through navigation, they maintain an open, fluid, heterogeneous, experimentally driven, context-valuing network. On the other side, through boundary building, they define membership, practices, language, and norms in ways that enable claims of authority in the domain.

It may seem that knowledge construction that results from boundary navigation and expansion of authority that results from boundary building are separate cause and effect stories. However, while we disaggregate them to provide clarity in our explanation of the system, they are fully intertwined. For example, cross-site visits serve to build boundaries, by expressing network expertise across sites and to campus decision makers. They also help local members to navigate boundaries across a power differential, since the presence of visitors prominent in the network often provides members additional access to decision makers at their own institution. The knowledge resources of the network influence claims of authority, and vice versa. When knowledge resources are limited, the perceived value of the network to outsiders is also limited, stifling any claim to authority. Conversely, when outsiders recognize network authority, membership grows and more resources are directed to the domain thereby increasing the knowledge assets of the network.

We hypothesize that boundary work may require less attention as the system progresses over time; network leaders will no longer need to build toward claims of authority as the network role in the system solidifies and practices become professionalized and normalized. The learning network may have disrupted the system and network leaders will need to adapt to address new system conditions. A group of isolated actors found each other and established a network. Now they are the experts within an increasingly sophisticated and recognized professional domain. Having applied pressures on the system, the network has contributed to shifting norms of practice and become an important feature of the conditions in a new morphogenic cycle.

2.6 Productive tension of critical boundary work: a meso-theory

We began with a summary of influential boundary concepts, a description of morphogenesis as a processual theory of systemic change, and insights from recent studies of transformative learning networks. We then provided evidence and analysis from our case study to explain boundary navigation, boundary building, and the overall effects of system elaboration over time. In this last section, we present a meso-theory to explain the critical role of different types of boundary work in the progression of a transformative learning network.

The network progression shown below (Figure 2.2) represents the social-interactional moment of morphogenesis from network beginnings (T2), to a more mature and transformative state where there is evidence of elaboration (T4). The two types of boundary work operate in productive tension, interdependently and synergistically contributing to this progression. Tracing through time, initial boundary navigation increases opportunity for network actors to organize into a collective and build knowledge through both exposure and co-construction across many types of boundaries. Second, boundary building progressively supports authority of the network and its members in the domain. As the network develops and members conduct both types of boundary work, authority and knowledge expand.

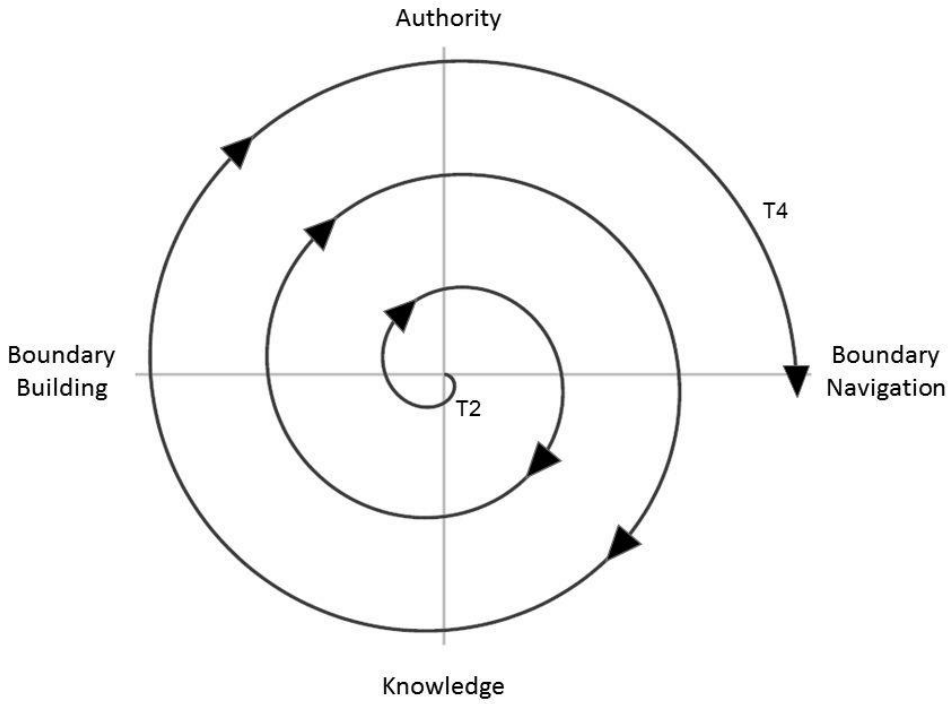


Figure 2.2 Productive tension of critical boundary work in network progression.

The time stamps in this processual diagram intentionally correspond with Archer's (2010, p. 238) simple diagram representing the passage of time (T) in morphogenesis. She disentangles the structural moment from T1 to T2, the social-interactional moment T2 to T3, and elaboration as observable at T4.

Aligning this progression with morphogenesis, boundary work occurs within the social-interactional moment of morphogenic cycles (Figure 2.2). New practices align with the transformation in progress and slowly replace old norms of practice, contributing to system elaboration. The next morphogenic cycle inherits the elaborated system conditions, including new structures, cultural conditions, and updated norms of practice. As this implies, the initiation of the network occurs in the context of pre-existing structures and conditions that support certain norms of practice. During this shift from norm-supporting conditions to disruption, there may already be instances of people in the system regularly engaging in non-normative practice. Conditions however, serve the normative practice of the given morphogenic cycle and challenge development and propagation of new practices that may come to dominate in subsequent cycles, when conditions are more favourable. Network capacity to disrupt the status quo is enhanced as knowledge and authority expand. System conditions begin to break down as more actors learn about and apply non-normative practices. When previously non-normative practices become the norm and are supported by conditions, the system has elaborated and moves into a new cycle. Conditions and actions are re-centered (Parker, 2000); the system has transformed.

2.7 Implications for practice

Understanding the dynamic, complex, and non-linear subtleties of transformation helps researchers and practitioners, ourselves included, to engage in robust conversations with partners about the nature of transformation. We can more comprehensively understand the path to transformative capacity when we can disentangle the causal powers of structures and agents. The way a system is structured and actions people take are both influenced by history, context, conditions, relationships, and interactions. A morphogenetic lens can help partners understand that neither top-down (structural) nor bottom-up (agentic) approaches will alone be sufficient to stimulate transformation. Transformation is slow, difficult to measure, and the result of many small acts and disruptions in a complex system (Tsoukas & Chia, 2002). Simply changing practice or conditions will not lead to transformation. Understanding how social interactions and conditions are intertwined may support change makers in establishing thoughtful directed action towards systemic change.

Network leaders and practitioners may be able to enhance practice when attuned to the dynamic tensions of boundary work. Thoughtful engagement with the dialectic between knowledge and authority is important for transformative capacity. With this in mind, network designers and practitioners can intentionally weigh enhanced learning opportunities offered by fluid navigable boundaries alongside increased influence of a network with clearly defined and maintained boundaries. Achievement of transformative capacity requires attention to both boundary navigation and boundary building practices, shifting dynamically between two types of effort while avoiding overemphasis on one or the other. In our observations, the work of managing boundaries in an inherently unbounded community is source of disagreement among distributed network leaderships. Each leader brings their own notions about how best to achieve change. While one person may privilege the multiple perspectives and welcoming nature of open network boundaries, another may privilege the strong organizational identity of a more homogeneous membership. Expansion of knowledge and authority in the system are not in conflict, but can be mutually constituted. The process however, challenges network leaders to accept change as a slow process and find a certain comfort with ambiguity and the unsung role of enabling the many small acts that support system elaboration.

2.8 Conclusion

We have offered a theory developed from intensive engagement in the case and practices of the network, and described critical aspects of practice in terms of contemporary theories from critical realism, social learning, planning, and processual philosophy. This in-depth processual look at the dynamism of a network as it progresses into a substantial force of both knowledge and influence through two types of boundary work propelling system transformation. Our processual approach and embracing of complexity demonstrate that transformative capacity stems from an intricate and dynamic set of processes. Synergistic across sites and scales, these processes offer a path for transformation that far exceed the potential of combined top-down or bottom-up approaches of institutions. We have offered the story of our case “beyond a surface description, to penetrate the logic behind observed temporal progressions” (Van de Ven & Poole, 2005 p. 1385; Tsoukus & Hatch, 2001). We

agree with the explanation of praxis as “practice interwoven with theory and theory informed by experience” (Innes & Booher, 2010, p. 89) and offer this theory

We conclude that when network leaders can treat boundaries dynamically, flexibly shifting emphasis between strength and fluidity, a learning network can enable transformation in a multi-scalar system. Two kinds of boundary work – building and navigating – are critical in developing transformative capacity and occur in productive tension. The effects of these two types of boundary work contribute to system elaboration in terms of both knowledge and authority. Networked approaches to transformational change must attend to both types of boundary work. Ours is a theory that links research on collaborative transformations with processual approaches to organizational studies and critical realism in that it harnesses the complexity of systems, intrinsic contradictions, ambiguity, and nuance in collaborative processes that have the potential shift systems that have been resistant to change.

3 EXPERTS AND SOJOURNERS IN LEARNING NETWORKS: PRACTICES FOR TRANSFORMATION

Transformative learning networks are a specific kind of network designed to support transformational change in complex systems across sites and scales. Detailed here are critical practices that occur across roles, sites, and various network substructures. These practices are not a set of ingredients for transformation, but exist in a dynamic tension and complex contexts of network sites. The multiple substructures structures and many practices and interactions occur as a symphony enabling transformation.

Results and narrative analysis describe four selected network substructures across which critical practices occur followed by thick description of the roles and specific practices of *experts* and *sojourners*. These roles require a brief explanation here, but more in-depth characterization occurs later. The expert role is to build the network, align the network with the larger system undergoing transformation, facilitate co-learning, and define what it means to be competent in the domain. The sojourner role is to develop local capacity and cultivate practice and to serve as a two-way bridge between institutions and the network. Sojourners conduct their work independent of the network, but leverage the network to gain legitimacy and learn across sites. Individuals may primarily serve one role, or be adept at moving between roles responding to the dynamics of each situation. The two roles are interdependent; supporting each other as the network develops transformative capacity. When network members play the expert role, they tend toward building boundaries around the network. When network members play the sojourner role they tend to be more engaged in boundary navigation practices.

Scholars and practitioners can find application for this work in both social-educational and social-ecological systems that have failed to shift into desired transformations through other mechanisms. This article encourages network leaders and site-based change makers to embrace the complexity of substructures and the many practices that enable learning networks to influence change across sites and scale by presenting evidence

from practice on how emergent approaches help to avoid rigidity, and increase the possibility of transformation in complex systems.

3.1 Transformative learning networks

Transformative learning networks are one of many types of networks that have emerged over the last decades as alternative processes to solve society's intractable problems. Castells (1996) described the rise of the network society and increasing importance of emergent networks in meeting societal challenges. More recently, Raab and Kenis (2009) describe a shift into a "society of networks" where the dominant collective social entities are groups of individuals and organizations intentionally organized around making change happen. Weber and Khademian capture the fluidity and complexity of networks describing them as, "the enduring exchange of relations established between organizations, individuals, and groups" (2008a, p. 334). Networks promise to connect stakeholders across sites facilitating participants to "co-create solutions to shared problems through collaborative processes that lead to continuous improvement or perhaps even disruptive innovation" (Torfing, Sørensen, & Røiseland, 2016, p.19).

Kapucu, Hu, and Khosa (2014) reviewed 677 network focused articles published in the public administration literature between 1998 and 2012. Although their review narrowed on articles where social network analysis tools were central (n=81), they more broadly noted a dearth of research on the roles of network individuals and the multiple network substructures across which dynamic relationships take place. Others recommend further study on the practices of key actors in networks and encourage a focus on the "softer dimensions" of collaborative networks (Weber & Khademian, 2008a, 2008b) or the intricate and understudied "human dynamics" associated with agency and identity in networks (Keast & Mandell, 2013). There is growing realization that many network studies tend to narrowly focus on performance and overemphasize the role of heroic leaders overshadowing interactional and social value created through more subtle network activities and interactions (Keast & Mandell, 2013; Knight 2002; Knight & Pye 2005). Processual views of organizational change also emphasize the transformative value of "non-heroic micro-

practices" cultivated and co-constructed through networks (Chia, 1999, 2014; Tsoukas & Chia, 2002).

Transformative learning networks are complex mechanisms designed to enhance collaborative learning in the complex systems they seek to transform. They come into play when bottom-up and top-down efforts have both failed to shift systems into desired changes. Goldstein and others (Goldstein, Chase, Frankel-Goldwater, Osborne-Gowey, Risien & Schweizer, 2017, p. 537) define transformative learning networks as, "inter-organizational voluntary collaboratives that nurture professional expertise" with the "potential to catalyze systemic change by disrupting old habits, fostering new relationships, and providing freedom to experiment". They conclude that networks foster transformative capacity when they are "designed and facilitated with a soft touch so that network members in different sites have the freedom to define their place and purpose within their system, as well as their role in bringing about a desired transformation." The loose and light structure of this type of learning network enables fluidity between roles, and otherwise disconnected efforts, setting the stage for transformative capacity to emerge (Goldstein et al., 2017). However, the details of the network substructures and comprehensive suite of practices and roles that contribute remain unexamined in systems where learning networks are central to transformation.

Complexity is critical in understanding networked approaches to transformational change and boundaries are a key aspect of complexity in these multi-sited, multi-scalar systems. Weber and Khademian (2008b) describe boundaries as multilateral and spanning across organizations, sectors, disciplines, and professional positions. These authors identify key actors in collaborative systems as "collaborative capacity builders" (2008a) and hone in on "crossing boundaries frequently and with ease" as one of six key practices in addressing wicked problems by maintaining fluid boundaries to support adaptability (2008b).

In addition to the emphasis on boundary navigation or boundary crossing in networks, as emphasized by Weber and Khademian (2008a; 2008b), boundary building should be included as important boundary work that demarcates groups from each other, and occurs in productive tension with boundary navigation (Risien & Goldstein, 2018). Boundaries in networks have two distinct functions and accordingly two sets of practices enabling these

functions. Risien and Goldstein (2018) demonstrate that boundary navigation practices expand a network's collective knowledge resources while boundary building increases a network's authority and influence in the system. They conclude that when network actors treat boundaries dynamically, shifting emphasis between strength and fluidity accordingly, the network gains transformative capacity and is able to stimulate and support change across sites and scales.

Communities of practice (CoP) theory (Lave & Wenger, 1991; Wenger, 1998; Wenger, 2000; Wenger, McDermott & Snyder, 2000) is also helpful in framing transformative processes that involve evolutions in practice, but limited to place-based bounded community structures. More recent insights, from *Learning in Landscapes of Practice* (Wenger-Trayner, E. & Wenger-Trayner, B., 2015), clarify practices that enable fluidity in complex systems, inclusive of many CoPs and the boundaries between them. Individuals in complex landscapes are sometimes building boundaries, and other times working across them. They customize their role and practices to suit a given situation as they navigate their complex landscapes of practice.

This article interprets the case evidence in terms of boundaries by examining: 1) network substructures in terms of how they support boundary navigation; 2) network roles in terms of the tensions of building boundaries around the network and maintaining open boundaries to grow the network; and 3) practices in tension and associated with building network identity and modulating across boundaries between the many communities in the complex landscape.

3.2 The National Alliance for Broader Impacts

The National Alliance for Broader Impacts (NABI) is a network born in 2013 from the need for research organizations, primarily universities, to address requirements of the NSF. Research funded through NSF must include efforts to meaningfully connect the research to societal benefits. Universities have found themselves ill equipped to meet these requirements because scientist lack training to address broader impacts, reward structures are unsupportive, and difficulties establishing necessary partnerships across disciplines and organizations (NABI, 2018). NABI serves as a professional home for the emerging domain

of broader impacts support. Designed as a large-scale and distributed CoP, the network collectively innovates, tests, and propagates best practices in the domain. NABI is host to a community of learners working together to build capacity to improve the connection between science and society. The network also serves as a resource to NSF and national organizations working to support broader impacts. A loose web of connections and relationships, with a variety of activity hubs, NABI's nearly 700 members participate with various levels of engagement. They are part of an observably growing population operating in the "third space" of universities performing critical boundary and brokerage roles (Bouwma-Gearhart, Perry & Prestly, 2012; Whitchurch, 2008, 2013). They are often central actors without positional authority, but who can influence policy, practice, and culture of university systems (Kezar, 2014). Many members do not identify with traditional instructional, research, or administrative roles in academia. An annual Summit is the network's central event for connection and learning. A listserv, individual communications between members, and cross-site visits sustain interactions between Summits. A principal, and small logistical staff, support network activities and engage a steering committee in leadership and an advisory board to help set the strategic direction of the network. Subcommittees of active members and leadership tackle specific needs such as financial planning, training, and event planning.

3.4 Methods

This study was conducted using participatory action research principles (Baum, MacDougall, & Smith, 2006; Chevalier & Buckles, 2013; McIntyre, 2008) with the author embedded as an active network member observing frequent network leadership calls, six biennial multi-day Steering Committee meetings, two multi-day meetings at NSF, three advisory board meetings and four annual full network gatherings since 2014.

Data includes field notes from observations attuned to discourse about boundaries, boundary work, collective action, members' identification with the network, and shared identity within the network. Semi-structured interviews (Bernard, 2011; Lofland, Snow, Anderson & Lofland, 1984; Weiss, 1995) (n=18) and a survey of network members (n=95) provided additional significant data.

The qualitative approach, with NABI as a single in-depth case, enabled capture of participant experiences in real time (George & Bennett, 2005; Goldstein & Butler, 2009). Emergent open coding procedures (Miles, Huberman, & Saldana, 2014) applied to field notes, transcripts, and open-ended survey responses resulted in 460 substantive excerpts broadly having to do with boundaries and boundary work. Excerpts, cross-referenced with interview and observational contexts, resulted in an initial coding scheme. Applied codes were iteratively refined, and ultimately, interpreted and organized into the typology present here. Network substructures were apparent through repeated descriptions in interviews and observations. Results are integrated with empirical and interpretive narrative analysis in the sections below.

3.5 Network substructures

Network substructures are often identified using quantitative social network analysis tools (Kapucu, Hu, & Khosa, 2014) and whole network structure, form, and governance types have been presented by several scholars (Keast, Mandell, Brown & Woolcock, 2004; Provan, Fish, & Sydow, 2007; Provan & Kenis, 2008; Raab & Kenis, 2009). Empirical examination of network substructures in the context of the practices they enable are not apparent in the literature.

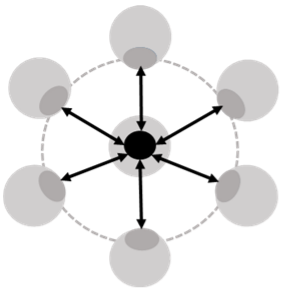
There are several substructures, within the transformative learning network, across which boundary work and other practices occur. To bring alignment between many disparate institutions and communities, the learning network leverages difference in institutional cultures, practices, and experiences and innovates shared practices that contribute to a transformed system. Network boundaries, around the network itself, are difficult to characterize and describe because they are generally permeable matching the loose and light structure of the network. For network practitioner, however, static bi-lateral conceptions of boundaries – for example the boundary between academia and the public or between scientists and outreach professionals – are not sufficient for understanding the nuance of the complex systems. A deeper look at the substructures in, and across, which actors perform critical practices is required.

Table 3.1 includes characteristics of substructure configurations. None of these are adequate to describe the several interconnected multilateral structures evidenced in NABI. The four selected, but far from exhaustive, examples below illustrate the variety and complexity of substructures. The characteristics in Table 3.1, along with member descriptions and field observations, are the foundation for the four substructures in figure 3.1.

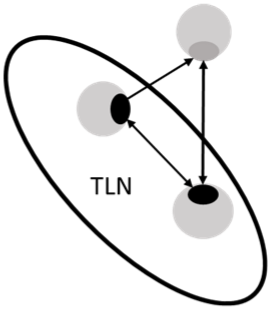
Table 3.1. Structural components of boundary work in a transformative learning network.

Horizontal	across organizations within organizations across units
Vertical	across organizations with power gradient within organizations across units with power gradient
Network Enhanced	network member to non-network group network member to non-network individual
Network Dependent	within network across difference on behalf of network with external groups or individuals

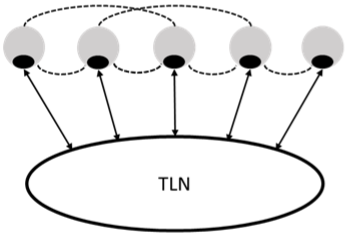
The hub and spoke example (Figure 3.1a) is prevalent in site-based activities. The network member serving as the hub connects across disciplines and programs within an institution and sometimes with local or regional organizations to develop broader impacts partnerships. The hub member acts on behalf of their institution, as a local broader impacts expert, at the same time serving shared network goals in a sojourner role. Members describe such work as supporting site-based connection across the many boundaries between organizations, practices, and scholarly disciplines. These hub and spoke structures often emerge independently from the network. Service as a local "hub" is a key shared practice among network members around which they cultivate relationship and align to the overall network goals. One member describes such site-based boundary work as "kind of like Uber, we don't have a lot of people but we have managed to have a lot of capacity based off of our network" referring to the regional community of people across multiple boundaries (interview, June 2017).



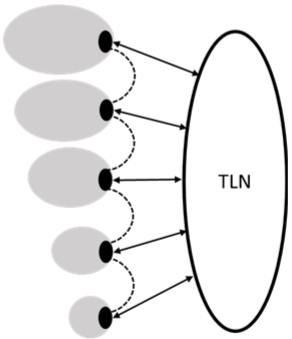
a. Hub-and-spoke site-based substructure
Horizontal, within organizations across units, networked enhanced. Network enhanced, network member to non-network group(s)



b. Diagonal visitor substructure
Diagonal, across organizations and power gradient. Network dependent, within the network across difference and network member acting on behalf of the network.



b. Peer-to-peer
Horizontal, across organizations. Network dependent, within the network across difference



d. Access to influencers
Vertical across organizations with power gradient. Network dependent within network across difference

Figure 3.1. Transformative Learning Network (TLN) substructures.

Black nodes are network members, black lines are flow of information through social interactions. Dark grey nodes are non-members receiving network information, light grey areas represent spheres of influence through which network knowledge moves creating a magnifying effect.

Members describe their hub and spoke work as enhanced by the network in two important ways. First, their engagement in the network invokes a sense of support, and feelings of being less alone, in what often are ill-defined local roles. Second, members frequently engage in collaborative learning with network peers and share best practices for working across local boundaries through the network events. Table 3.2, discussed in more detail later, describes many of the specific activities conducted in this substructure as part of the sojourner of practices. One member describes the hub role, saying, "I run a community of practice for people who do education and outreach on my campus and off campus – groups like museums, people from other universities – through this central network, I keep tabs on many things going on at my campus and in my community" (interview, June 2017).

The diagonal example (Figure 3.1b) often occurs during site visits when local members invite and host expert members, usually involved in the network leadership, for a campus visit. A critical part of the expert visit is joining the local member in meetings with local decision-makers to secure or grow administrative and fiscal support for local progress towards shared network goals. The local member may have already conducted such vertical boundary work engaging local decision makers, but many report that an outside expert voice enhances access to high-level administrators.

Expert visitors also provide training for faculty, give campus seminars, and talk to administrators about developments in broader impacts practice at federal agencies. Visitors cross the horizontal boundary across institutions, and simultaneously the vertical boundaries across a power gradient, resulting in diagonal work. The visiting expert is a spokesperson for the network collective expertise with position and power as a leader in a national organization. The network guides and emboldens both the local member and the expert visitor in these interactions. One such expert visitor describes the diagonal work, "when I work with administrators, I want them to *really* understand what it is like in the trenches" (interview, October 2016).

The peer-to-peer substructure (Figure 3.1c) illustrates the dominant substructure in which the network, through gatherings and listserv communication, provides members an interactional learning space for sharing and innovating practice. The primary boundary

worked is horizontal across institutions with unique cultures and conditions. This example illustrates members' participation in both emergent and planned co-learning dependent on the core activities and coordination of the network. Members also reach out to each other outside of network hosted events, but cite the network as primary host for sharing ideas and innovations. One member describes the advantages of working through the network, as opposed to locally at their institution, this way, "universities are autocratic, but I never get that sense with NABI, it's like 'we all have to work together on this, it's a joint problem and let's pool our resources together'; that kind of discussion is frankly rare" (interview, June 2017).

Figure 3.1d illustrates how the network serves to enable access to policy influencers and decision makers from federal agencies and associations active in the system transformation. Like the peer-to-peer example, this is dependent on network facilitated gatherings and communication through the listserv. The primary boundaries worked in this example are vertical across organizations along a power gradient. The network integrates the peer members with influencers that can advocate for the network shared goals at scale. The Summits provide opportunities for sojourners and experts alike to collectively access and inform decision makers and influencers across scales. For example, policy directors from major higher education and research associations regularly attend gatherings to learn about members' experiences and shared challenges. They use that information to optimize how they advocate for policies and practices that support broader impacts. Reciprocally, such influential individuals provide up to date information on national scale initiatives that may impact members' local work and the network as a collective. Member access to influencers (and vice versa) guides and aligns practice across scales. One member describes how the network facilitates such access, "I see so many organizations represented at NABI, [at my institution] we are not anywhere near D.C., we are not next to the people who are getting things done at the highest levels, but there are people in NABI who are much more tied to what is happening nationally… that's something we cannot do on our own" (interview, June 2017).

3.6 Practices of experts and sojourners

The previous section describes dynamic and multilateral boundaries and substructures observed in this case study. Here focus shifts to the distinct, but interdependent, roles and practices of experts and sojourners.

While specific practices are associated with specific roles it is important to note that actors operate in the system with substantial fluidity, moving between roles and scales responding to the dynamics of each situation. For example, several members serve on the network leadership and epitomize the expert role in the whole network setting, but report typical sojourner practices as the driver for participation of the network, "I am just as excited as everyone else to attend the sessions and find out how people are solving their problems" (observation, April 2016). The opposite is also true. A member who does not serve on the network leadership, and may not be positioned as an expert, but still engage in expert practices such as working to clarify the language used in broader impacts discourse. Expert and sojourner are then categories for practices individuals engage in while playing different roles in the system. In the expert role, individuals tend to be centrally situated in the network conducting practices that build boundaries around, and identity within, the network. In the sojourner role members are relatively peripheral in the network focusing their practice centrally as experts at their own campus. Sojourners prioritize local needs and seek alignment with the network on local terms.

3.6.1 Expert practice

Members who assume the expert role build the network identity and network boundaries, align the network with the larger system, and facilitate co-learning among members. Experts demarcate who is in from who is out of the network (see Gieryn, 1983 and Tajfel, 1982). They are simultaneously balancing boundary building with expanding the membership and thereby collective knowledge and reach of the network (Risien & Goldstein, 2018). They serve to develop and maintain what it means to be competent in the domain (Wenger, 1998) with high accountability to the domain (Wenger-Trayner, E. & Wenger-Trayner, B., 2015). They use the network to test, ground, and innovate broader impacts practice. They cultivate a membership to ensure a variety of perspectives contribute to the

developing field. Many experts self-identify as innovators monitoring and focusing their energy on the collective impact and overall vision of the network.

The analysis of boundary related data uncovered a suite of expert practices (Table 3.2) in four primary categories: building network identity; focusing the scope of the network; stewarding competence in the domain; and advocating at the collective scale. Descriptions of critical expert practices appear below organized by category.

E1: Building community across the many organizations involved in the emerging broader impacts domain is an aim of several expert practices. While these dispersed individuals and programs have a history of addressing broader impacts, the network provided the first opportunity for facilitated interaction and community building in the domain. Experts established a set of network norms privileging permeable boundaries and offering members broad connectivity with a collective. They encourage members in their sojourner roles to serve as ambassadors for the shared network goals and to express their connection to the larger initiative around broader impacts in their local work. One member describes the unbounded nature of the network, "NABI has got to be the most welcoming, friendly, genial group of professionals I have ever come across, there is no criticizing or grandstanding, you don't see that much, it is a respect thing" (interview, June 2017).

Heterogeneity enables a variety of good ideas and practices from a diverse set of members to coalesce in the network. One expert member recognized this characteristic, "the diversity of the individuals who participate in NABI is a strength" (interview, May 2017); nearly 100 percent of survey respondents agreed with this sentiment. Experts take on the job of casting a wide enough net to maximize learning opportunity and generate important connections to other domains or organizations in the system.

Experts encourage the membership to engage in vertical integration on their campuses, but also at the national level. They use their own ambassador practices as an example to follow. One member describes how the network as a collective that can be leveraged, "there is a huge push from our university to increase our standing, to engage nationally, NABI is a huge part of that" (interview, May 2015).

The open boundaries and low barriers to membership described above are in tension with how experts also manage to build identity and define the criteria for membership. Experts do not achieve this through intentional exclusion, but allow self-selection to regulate membership. There is an ongoing debate about who is in and who is out. In the course of debate, some experts expose their predisposition toward clarity of boundaries and desire to maintain a manageable network size, while others prioritize permeability, citing the opportunities for growth and learning.

Discussions around developing a shared language and understanding of broader impacts indicate identity building work. Experts engage in discourse about the need for thoughtful use of language to establish meaning in this new domain. In one such discussion an expert brought up the network's "linguistic footprint" noting that, "NABI may be giving NSF the language to talk about broader impacts in a more meaningful way" (observation, April 2015). Other discussions among experts have focused on what it means to be a broader impacts professional. Attention to the use of language also influences the expert practices of focusing scope and stewarding competence.

Overall, experts align the network with other key entities in the system and provide a "safe space" for members who are "looking for support [from leadership] at their institution and coming to NABI for ideas, community, and support" (observation, October 2015). Rather than just building a network where they feel belonging, experts are intentional about providing belonging for a variety of members. Anyone who shares the larger mission and moral imperative, improving connections between science and society, can productively engage.

E2: Focusing scope requires experts to understand how the network is situated in the system, identify problems in the system, and prioritize network actions around those problems while simultaneously aligning with national and local scale needs. NABI is "trying to find its place among organizations involved in research" (survey, May 2017). Experts engage with external organizations and people to understand problems in the system and prioritize which problems the network should collectively address. For example, experts regularly meet with NSF staff to discuss how NABI can inform and support the agency's

progress on broader impacts. A group of experts also met with members of the National Science Board and a congressional staffer to learn about planned policy activity in relation to broader impacts. Experts use what they learn from such interactions to align the network with national-level policy and practices.

Experts gather information from stakeholders throughout the system to help them problematize around broader impacts. For example, the academic promotion and tenure process is widely considered in the network to constrain transformation as it privileges grant income and discipline specific peer reviewed publication over achievement of broader impacts. Network experts grapple with gaining a full understanding of scientists' lived experience of the reward structure to identify the degree to which the network should prioritize action to improve this situation.

Practices to cultivate boundaries around the network are critical in focusing scope as the network is a reflection of the collective knowledge and perspective of the membership. One member describes advantages network demarcation expressing concerns about increased heterogeneity, "there's a lot of solidarity among those of us doing similar kinds of work…if we lost that, if we became diluted, that would be disappointing" (interview, June 2017). These practices occur in tension with efforts to keep boundaries permeable and navigable to building community.

E3: Stewarding competence aligns with the network goal of building a distributed CoP, where the experts are holders of what it means to be competent in the domain. Such practices contribute to building boundaries around the network community and occur with acknowledgement of how expertise relies, in part, on one's ability to tap into network collective knowledge. Early dialog includes statements of vulnerability articulating that nobody is an expert here, we are all figuring this out together (observations, April 2015; October 2015; April 2016). After two years of development statements begin to counteract the vulnerability sentiment, "I am an expert, if anyone is, I am, we are" (observation, October 2016). External decision makers also now acknowledge the "great collective knowledge" of the membership (observation, April 2016).

Part of stewarding competence is promoting and guiding scholarship around broader impacts. Experts have contributed to peer-reviewed journals, share their broader impacts research at Summits, and recently made significant progress toward establishing a dedicated broader impacts journal. A group of experts collaboratively developed a *Guiding Principles* document to steer broader impacts practices across the system (NABI, 2016). Most active members report that they use the document when supporting scientists. The NABI community has asked for more resources that synthesize knowledge and guide practice in specific areas such as evaluation and broadening diversity in the sciences. At the time of submission a group of experts was actively seeking substantial financial support to create and broadly disseminate additional resources and training that reflect the network collective knowledge and elevate broader impacts practice across the scientific community.

E4: Experts advocate for national-scale systems and processes that better enable success across sites. They keep moral imperative, "I do this for my kids, for the generations that come after me" (interview, October 2015), and "bigger picture" central as they advocate. High-level influencers engaged in the network invite network leadership to discuss issues in the domain and the role of the network with NSF leadership, legislative staff, and organizations that develop policy on behalf of the scientific community. This high-level work, emerges from top-level interactions (Figure 3.1d) and maintains the network as a force of transformation in the system where experts are the stewards and their practices build authority of the network in the system (Risien & Goldstein, 2018).

Table 3.2. Critical practices of experts and sojourners in a transformative learning network.

Experts/Central Participation/National	Sojourners/Peripheral Participation/Local
E1: Build Community *E1.1 - foster member belonging & development* *E1.2 - empower members as ambassadors* *E1.3 - cultivate shared language/understanding* *E1.4 - cultivate member identification*	**S1: Foster Expressibility / Imagination** *S1.1 - engage outsiders in domain* *S1.2 - expose actors to similarities between groups* *S1.3 - act as a personalized guide*
E2: Focus Scope *E2.1 - problematize in the system* *E2.2 - prioritize activity within domain* *E2.3 - articulate/cultivate network boundaries* *E2.4 - align with national scale needs/policy*	**S2: Cultivate Collaboration** *S2.1 - broker new relationships build trust* *S2.2 - identify and leverage points of alignment* *S2.3 - coordinate multiple entities* *S2.4 - maintain robust professional network*
E3: Steward Competence *E3.1 - claim and grow expertise in the domain* *E3.2 - conduct/guide scholarship in the domain* *E3.3 - develop, identify, articulate best practices* *E3.4 - provide resources and advice to outsiders*	**S3: Broker Information/Service** *S3.1 - share expert provided information* *S3.2 - synthesize or interpret available information* *S3.3 - share undocumented stories & experiences* *S3.4 - provide direct service, support, and training*
E4: Advocate	**S4: Advocate**

3.6.2 Sojourner practice

Sojourners, not responsible to build a network and develop the domain at scale, focus on improving local broader impacts activities engaging a variety of local actors to support progress. Here, the term sojourner describes the role a member employs as they modulate between co-learning in the network and more central practices at their home institution. Sojourners identify boundary work, specifically brokering, as key practices and dispositions of their practice. The critical mass of like-minded sojourners was a driving force initiating the network and members sharing their site-based experiences remains an essential focus of co-learning. Experts look to their sojourner selves and colleagues to ground the network in everyday experiences of practice. Relative to experts, the sojourners have less accountability

to the network, but high accountability to their own institution. Sojourner practice occurs across all of the four substructures described earlier with an emphasis is on expanding local knowledgeability by navigating site-level boundaries (Figure 3.1a). The sojourner finds alignment within their own institution and bolsters their success by aligning with the network. They work with an array of collaborators from across disciplines, organizations, positions, and practices. They foster expressibility and imagination as they cultivate practical partnerships, serving as brokers of information, and advocating for improved broader impact practices.

Sojourners drive an iterative learning cycle, connecting site-based innovations with the depth of knowledge and experience in the network. They consistently report that the network provides them credibility as knowledgeable individuals in the system, enabling them as competent providers of information about broader impacts.

S1: Fostering expressibility and imagination are two critical aspects, subtly enabled by sojourners, of personal identification that individuals learn in a complex landscapes of practice. Imagination is being able to imagine oneself as part of a community new or different from the communities with which one normally engages. Expressibility is the degree to which one can express who they are in a given community. Enhanced imagination and expressibility may influence individual choices of what communities and with whom to commit their energies (Wenger-Trayner, E. & Wenger-Trayner, B., 2015). One member describes their practice helping university scientists overcome "their uncomfortable feeling that there has to be difference in the way we communicate with minority people" (interview, June 2017). This sojourner, like many others, is a personal guide for scientists, exposing common ground with a community that shares the natural curiosity that drives science. The sojourner helps scientists shift their thinking, from a compliance frame, e.g. "I just have to do this stuff, because NSF requires it", to imagining that they can find common interests with an underserved community. Exposing similarities, not only differences, across social boundaries helps scientists see that these learners are "just regular people, they are smart, curious and interested". By personally guiding people across such boundaries, the sojourner enables each group to see what they have in common, increasing fluidity between groups.

S2: Cultivating collaboration includes sojourners' practices that broker new relationships, cultivate practical partnerships, and build trust across different communities. They identify and leverage points of alignment across different CoPs codifying potential for productive collaborations. For example, a scientist may have an interest in public engagement, but not a venue or science communication skills to follow through. Sojourners often connect such scientists with the training they need and establish mutually beneficial partnerships with facilities such as science centers with built-in audiences. Sojourners maintain robust social-professional networks to facilitate such collaborations and demonstrate skill in coordinating multiple disparate entities for whom collaborative potential may not be otherwise obvious. One member describes their practice as, "connecting [scientists] to the media, to museums, to schools, to evaluators; a lot of it is just making the connections to the outside organizations, people and professionals, it can be really difficult" (interview, June 2017). Another member describes this work, "it's knowing a lot of people, partners and programs…if I didn't have my ear to the ground, being familiar with what's happening on campus [I could not help scientists] meeting people in the community and making connections" (interview, June 2017). Sojourners spend significant energy weaving the web that connects people, listening, and learning to contribute to local broader impacts progress.

S3: Sojourners broker information and provide services to their local networks. There are four dominant and recurrent examples of sojourners conducting information brokerage services in alignment with the NABI network goals. First, using the previously referenced *Guiding Principles*, sojourners provide information about broader impacts development and practice to scientists that may not already have the skills to competently develop broader impacts plans.

Second, sojourners gather information at Summits or through direct requests for information from their network peers. They contextualize information for maximum interest and utility on their campus and for individuals whom they are supporting. This may include changes in NSF review practices, anticipated legislative action, or specific broader impacts framing that may gain positive reviews of broader impacts plans. For example, emphasis on

broadening participation in science is of increasing priority for NSF. Sojourners learn about this at network gatherings and come to understand changes at NSF by listening to NSF staff and discussing early experiences of these changes with their peers.

Third, sojourners gather stories of success and failure from their peers expanding their repertoire of justifications and pathways to help scientists plan and design broader impacts. Finally, sojourners provide direct support to scientists in the form of training, proposal development, and evaluation services. NABI provides sojourners specific content from which they can draw to develop targeted local trainings. The inverse is also true, sojourners develop resources and trainings on their campuses and share those with the network.

S4: Sojourners advocate at the local level. Many report engaging with upper-level administrators at their institution to advocate for local broader impacts support positions and programs. Often aided by the diagonal substructure (Figure 3.1b), sojourners highlight their role in the network and present themselves as extensions of the collective knowledge and NABI's national standing. Sojourners share strategies with each other on connecting broader impacts to local administrative priorities such as boosting public relations or competing with other universities. One member appealed to leadership, "I tell them, 'hey look, there is money on the table [for broader impacts], we can direct it to our strategic planning goals if we do it carefully'" (interview, May 2017). Others report using the moral imperative, improving the connections between science and society, as a basis for advocacy noting, however, that administrators are compelled more by "return on investment" via more competitive grant proposals.

The results and analysis in this section reflect NABI as a case study and application to other networks will require thoughtful cross-walking. The next section includes insights for how understanding of network substructures, roles, and practices may assist network leaders, designers, members, and evaluators in accessing the full potential of a network.

3.7 Lessons Learned

A comprehensive evaluation of NABI highlights that network impact radiates out from active members who have a magnifying effect in the system. Such impact is difficult to

measure or causally link to network activity. This study uncovers and examines some mechanisms for this magnifying effect in terms of the variety of substructures and practices that can enable feedback loops to ensure that the network itself learns and evolves via input and knowledge that flows between member sites, partner organizations, and the network as a collective. For example, a network member employing the hub and spoke substructure (Figure 3.1a) may gather information about the pitfalls associated with the short-term nature of broader impacts funding. The issue is then discussed and synthesized among peers (Figure 3.1c); after which a clear message of the specific nature and effect of short-term funding is conveyed to influencers in the system (Figure 3.1d). The process works in reverse too. Influencers share a significant anticipated shift in practice at NSF with network members (Figure 3.1d). Member peers then work together to assess the implications of the shift and collaboratively develop strategies to cope with the change (Figure 3.1c). Members then share the anticipated change coupled with ideas on how local stakeholders should prepare for and address the anticipated shift (Figures 3.1a and 3.1b).

Multi-sited learning networks are a mechanism for scaling up the CoP model; limited in that it is place-based and bounded failing to attend to the complexity of the system (Lave & Wenger, 1998; Wenger, 2000). On the other hand, learning networks are designed to transform the system more comprehensively across sites and scales. They magnify the flow of information about practice by providing the superstructure for experts to work at the center of the community, and sojourners to fluidly enrich the network with an array of site-based knowledge and experience.

The substructures are critical to the transformative potential of NABI enabling flow of information in all directions across locations and scales. These substructures were the result of experts in leadership roles being responsive to the needs of sojourners who are responsive to the needs of their own institutions. Such mechanisms can be built-in to learning networks enabling tracking and monitoring of how they are used and the outcomes they produce. For example, recognition of the diagonal structure (Figure 3.1b) its role enhancing site-based support and resources would allow development of an intentional site visit program inclusive of an evaluation protocol to track event outcomes. Practitioners,

sojourners and experts alike, can also use these substructures as an anchor for adaptive processes as they seek to balance site-based and scaled transformation goals.

Network leaders, designers, and members can couple the practices presented here with their own experiences to expand perspectives on the contributions of a broad suite practices. Observations included several debates about practice including debates on how to bound membership, use internet collaborative platforms, involve for-profit entities, and accept sponsorship. During these debates individuals elevated the practices relevant to their own previous experiences and argued on that basis. This set of practices demonstrates that transformative learning networks are complex endeavors. Many practices that seem to counteract one another can in fact productively co-occur progressing the network in terms of expanding authority and knowledge resources (Risien & Goldstein, 2018). Practitioners do not need to choose one or the other, rather weave together multiple practices allowing individuals to gravitate toward those practices and roles that suit their skills and dispositions.

Prescribed practices and defined roles are not necessary to develop transformative capacity. Transformation across sites and scales is not the result of single heroic actors nor bottom-up processes. It emerges from a concert of interdependent roles and practices, central or peripheral, expert or sojourner. By understanding and valuing both expert and sojourner roles and practices network designers may enhance transformative capacity.

3.8 Conclusion

Risien & Goldstein (2018) conclude that two kinds of boundary work – building and navigating – are critical in developing transformative capacity and occur in productive tension growing network authority and knowledge respectively. They assert that networked approaches to transformational change must attend to both types of boundary work. This article details the specific roles, practices, and substructures that, when woven together, can develop transformative capacity. This deep dive into a single case answers the call to examine network substructures and individual roles (Kapucu et al., 2014), explain the "human dynamics" in a network (Keast & Mandell, 2013); and describe the key practices of actors that enable the "softer side" of network success (Weber & Khademian, 2008a, 2008b). Learning networks do not develop as hierarchical organizational forms, but instead emerge as

a complex suite of fluid and interwoven structures, roles, and practices. Network success is not the result of heroic leadership or rigid attempts to define organizational structures. Success rather depends on leveraging variety and supporting collaborative learning across sites and scales.

There is inherent conflict in distilling the many moving parts across multilateral boundaries in a complex systems. Clarity requires categorizing, but this can detract from the true complexity of the system. Likewise, disaggregated practices presented in the typology are not a simple list of ingredients for network practice; their power lies in how they are interconnected. This analysis provides practitioners a road map of the suite of activities that have helped NABI create a positive environment on the path to transformation. In application, practitioners will weave these and other practices together in response to their own context.

The substructures and sets of practices are useful to examine learning networks or similar social innovations working to disrupt the status quo towards transformation of complex systems. Multiple substructures and a variety of expert and sojourner actions are all important and contribute to the transformative potential of learning networks. Network leaders should avoid prioritizing specific structures, roles, or practices and instead embrace complexity mindful that all structures and actors all have a role to play. Transformative learning networks rely on the interplay between sojourner and expert roles to make progress toward systemic change that extends across sites and scales.

UNVEILING IMPACT IDENTITIES: A PATH FOR CONNECTING SCIENCE AND SOCIETY

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4 UNVEILING IMPACT IDENTITIES: A PATH FOR CONNECTING SCIENCE AND SOCIETY

Over the course of their career, most scientists cultivate an identity aligned to the research they conduct, their contribution to their professional community, and the relationships and partnerships they form within their scientific community. Scientists develop this self-concept and identity by distinguishing themselves from others (mostly non-scientists) through a process of "social differentiation" (Tajfel 1982; Tajfel & Turner 1986). The identity as a scientist is often limited to expressing oneself to professional peers and does not ordinarily connect scientists to public audiences. Here we explore how a narrow perspective on scientists' professional identities has implications for the way the scientific community relates to society. We describe benefits when individual researchers find alignment between their research efforts and public engagement with science. We posit that an expanded professional identity, which we refer to as impact identity, can enable researchers to find a productive way to leverage their research for a broader common good and make strategic and efficient use of a growing system of support mechanisms at the intersection of science and society.

Here we use the terms "scientists" to encompass those who investigate natural and physical phenomena. However, we maintain these concepts are relevant to engineers, computer scientists, social scientists, and interdisciplinary and applied scientists. We use "success" in two ways with implicit meanings. With regard to broader impacts, success is still quite subjective and the topic of ongoing study and evaluation; for our purposes success refers to situations in which scientists and audiences engaged in science perceive a benefit from broader impacts activity. The concept of a successful scientist differs between disciplines and institutions, and evolves over time. In general, we consider a successful scientist is one who is considered successful by their peers.

Impact identity results from a thoughtful and intentional integration of a scientist's multidimensional self-concept. It blends the researcher, someone who aims at contributing knowledge within a scientific discipline, with the engaged scholar, or someone who ensures results of this research benefit society. Impact identity incorporates a scientist's discipline

and scholarship; personal preferences, capacities, and skills; institutional context, and the various communities or social settings in which s/he participates. By integrating these various aspects of a scientist's skills, interests and opportunities, we expect that a well-developed impact identity can foster approaches to broader impacts that result in better outcomes for the scientist and for society. For scientists, this manifests as more rewarding experiences conducting public engagement in a way that represents them as a whole person. The experiences of public audiences who take part in these public engagement activities should also be improved.

Unveiling and applying impact identity is certainly not enough to achieve high-quality broader impacts. Scientists must also assemble, and make use of, a supportive structure of partnerships and relationships that enable broader impacts success. Fortunately, a growing number of professionals at universities and organizations that engage the public can serve as brokers who help scientists develop relationships and skills and garner the resources necessary to explore the best ways to achieve broader impacts. Well-developed impact identities can serve as a glue between scientists and those who support them, allowing scientists to choose between the myriad of options that exist for connecting public audiences to their research (Storksdieck et al., 2016).

In the sections below, we ground the concept of impact identity in relevant theory about the social boundaries between science, as a subsystem of society, and other sectors of society. We consider the way the scientific enterprise is situated in society; both demarcated from, and in fluid dynamic exchange with, other sectors of society. We then describe societal impacts of research in terms of broader impacts, focusing on the current funding and professional landscape of science, particularly as it applies to the NSF. We include two examples of scientists with well-established impact identities. We end with principles for understanding critical dimensions of scientists' identities and an approach to developing impact identity that can help move forward or advance their broader impacts work.

4.1 Science and society: theory to inform impact identity

While we live in a "golden age of science" with extraordinary rapid scientific discovery, we are also experiencing anti-science activism that is couched in a narrative of scientists and science as the "other", apart from society and its interests (Hockfield, 2018; Holt, 2018). Anti-science attitudes play off established social phenomena demarcating the scientific community from non-science realms of society in a way that bestows scientists with authority on scientific process and knowledge about natural and physical phenomena (Gieryn, 1983). Assigning authority to a professional class is not limited to science, but is something that is just as true for lawyers, physicians, electricians, and most other professions. The "boundary" between science and other sectors of society is maintained, in part, by strong scientific identities and social interactions that maintain distinctions between groups (Tajfel & Turner, 1986). Such boundaries and identities between the realms of science and non-science have been a topic of interest and study for decades (Abbot, 1995, 1998; Clarke et al., 2013; Franzen et al., 2012; Gieryn, 1983, 1995, 1999; Ibarra, 1999; Lamont & Molnár, 2002; Weingart & Lentsch, 2008).

The demarcation between science and non-science protects the integrity of systematic scientific investigations that build knowledge about the world (Weingart & Lentsch, 2008). On the other hand, strong identities and social boundaries come with distinct practices and worldviews that can isolate the scientific community from other sectors of society (Abbott, 1988; Gieryn, 1995; Seo &, Creed 2002). One prominent example where science integrity and norms clash with other sectors of society is the conflict about whether to teach creationism, intelligent design, or evolution in schools. This conflict over which group can claim authority on how we should educate children in the core principles of the life sciences pits science against religion (Brooke, 1991).

Maintenance of social boundaries between an expert community and society comes as a cost. For instance, the typical forms of communication, including the use of expert language in peer-reviewed journal articles that themselves are mostly inaccessible to non-scientists limits non-scientists' access to the resources and knowledge of science (Lamont & Molnár, 2002). Again, this phenomenon is not limited to science, but it reduces opportunities

for the public to engage in meaningful science experiences and for scientists to engage with the public. Fortunately, boundaries between the realms of science and non-science are unstable, always shifting and being redrawn (Gieryn, 1983, 1995), as citizen science powerfully demonstrates (Bonney et al., 2014). Professional identities also shift when individuals experiment with different professional selves (Clarke et al., 2013; Ibarra, 1999). Scientists are increasingly required to engage in activities that show the societal impact of their research. Scientists can more easily engage with the public, and vice versa, when they see themselves as part of a larger societal whole, rather than apart from it. Blurring boundaries, and thus integrating science as part of society, therefore opens scientists to potentially rich and innovative exchange with non-scientists (Engeström, 2009; Wenger-Trayner, E. & Wenger-Trayner, B. 2015).

4.2 Broader impacts and the science funding landscape

Over the last several decades there has been a steady decline in the portion of the federal budget allocated to research (OMB, 2017), increasing the sense of fierce competition for funding among scientists (Mervis, 2017). Meanwhile, NSF has expanded proposal requirements beyond intellectual merit, explicitly requiring broader impact plans to address societal benefits of the federal research enterprise (NSF, 2014). The term broader impacts encompasses a wide variety of potential activities, partnerships, and processes that may enhance the societal benefits of funded research. The NSF explicitly avoids prescribing activities that qualify as broader impacts. Nonetheless, it provides examples such as enhancing public safety, national security, economic prosperity, science learning, broadening participation in the scientific enterprise, and public engagement with science. Although broader impacts include a wide array of activities, outreach and public engagement tend to dominate in fields such as biology, ecology, astronomy or physics where commercialization is of less importance. Incidentally, the NSF is not the only science agency to pose such challenges to the scientific community. Medical research funded by the National Institutes of Health fits along an implied impact pathway from bench to bedside, with an ultimate goal of improving human health. Department of Education funding similarly aims at improving

teaching and learning. Agencies such as NASA and NOAA tie funding to mission success. The NSF broader impacts criterion achieved a new significance over the last few years, though. Expectations for the quality of broader impact component of NSF proposals have increased considerably, elevating broader impacts as a funding criterion from a marginal consideration to one highly relevant to funding success (NABI, 2018).

Many scientists piece together a patchwork of broader impacts activities across several programs and grants, addressing them more as a required box to check than an integral aspect of their professional work (Malcom, 2018). However, a widely untapped opportunity exists for researchers to instead expand their professional identities and build a legacy of impacts over the arc of their science career, similar to what successful researchers already do with their research portfolio and research direction. Building one's impact identity and developing a portfolio of complementary projects can feel out of reach and under-supported. Lack of professional preparation, mismatched institutional reward structures, and norms of practice within disciplines are common barriers to systematically addressing broader impacts as an integral part of research itself. Many scientists overcome these constraints through bootstrapping, managing to develop the necessary partnerships that help them create successful broader impacts activities (Risien & Nilson, 2018a). Below are two examples of seasoned scientists who integrated the many dimensions of their identities in order to develop outreach and engagement activities that fit their interests, capacities, societal needs, and research. They both started with modest projects built out of initial partnerships. As they have developed in their careers, those modest beginnings gave rise to a series of increasingly impactful projects, each growing out of the success of the previous. Both scientists have made commendable contributions by blurring the boundaries between science and other sectors of society. They leave in their wake a legacy of broader impacts.

4.2.1 Building the Trail of Time with underrepresented students

The *Trail of Time Exhibition* is a fully accessible three-mile-long interpretive timeline trail along the Grand Canyon's south rim that interprets the nearly two Billion years of Earth's history preserved in Canyon rocks. The trail represents the final product of a

systematic effort around broader impacts by University of New Mexico geologist Dr. Karl Karlstrom. He began researching in the Grand Canyon in 1983. A decade later, Karlstrom, his colleague Dr. Laura Crossey, and others wanted to use their emerging research findings to enhance public science literacy around Grand Canyon geology. They recognized that the canyon offered a unique opportunity for visitors to immerse themselves in geology. They started with simple questions about what park visitors may, or may not, be learning about geology. To establish the mechanisms to answer this question they cultivated partnerships from "the top" with park superintendents and from "the base" with park rangers. They worked to collaboratively build their long-term impact plan through a consensus process with partners, along the way bringing underrepresented students into this work. The plan focused on where the goals of scientists, park rangers, and administrators overlapped. Following an NSF planning award, the partnership eventually secured significant funding to develop and build the exhibition. By then the team included academics, students, park interpreters, museum evaluators, and exhibit design specialists. The exhibition opened in 2010 and soon after received an award from the National Association for Interpretation. The team now continues to use Trail of Time for research on learning and teaching in formal and informal contexts. A logical extension of the geologists' identity as scholars to researchers on how people learn geology. They also work to export the concepts behind Trail of Time to other parks and educational venues throughout the Colorado Plateau.

The enduring installation is not the only success of their commitment to achieve broader societal impacts with their research. Along the way, Karlstrom and Crossey took on the role and responsibility to mentor several underrepresented students through their transition from undergraduate to graduate studies. They helped students develop personal and professional networks that enable students to more fully participate and progress in their education. This story highlights the years of persistence and ample energy to cultivate partnerships. With initially limited resources, the team was able to create an effective and enduring geoscience experience. Along the way, they provided many of students with motivation to connect their own scientific inquiry to effective public outreach. The story also

highlights the extension of the geologists' identity as scholars in geology to becoming scholars of geology learning for all.

4.2.2 Cascading impacts of reconnecting people with trees

Dr. Nalini Nadkarni's personal mission is to engage those with no access to forests in learning about forest ecology. Early in her career Nadkarni was struck by how most science outreach "preaches to the choir" and only involves those already interested and engaged in science learning activities. Nadkarni's strong sense that learning about forests and plants should be available to all made her decide to reach new audiences in unexpected places. One group, not commonly considered as an audience for science, is the more than two million inmates in the nation's prisons and jails. Early on Nadkarni visited inmates and shared her enthusiasm for science and her love of forests. These visits opened a world of possibility; she enlisted the prison system as partner, and engaged inmates as co-producers to cultivate mosses to repopulate Pacific Northwest forests affected by destructive moss collection for the floral industry. This work led to a sustainability lecture series at the prison, which led to sustainability programing in the prison, and prisoners raising endangered tree frogs to support wild populations. Hers is a story of cascading impacts that are possible when a scientist integrates several dimensions of their identity in their professional life. Nadkarni has spent a career studying trees and contributing to understanding the value of the canopy ecosystem. She also cultivated necessary tools and partnerships to engage those with little access to nature as part of her sense of social justice and her deep belief in the beauty and fascination that forests hold even for those who cannot visit. Her journey centers on her goal of finding common ground with audiences who have little access to science, and who may not value science unless they experience authentic encounters in which scientists care.

Karlstrom and Nadkarni's stories serve as examples of successful scientists with strongly developed impact identities. They have done their broader impacts without sacrificing intellectual integrity or disciplinary standing. They have instead leveraged scientific success as an asset to enhance their impact. Karlstrom and Nadkarni derive substantial personal and professional satisfaction from their impacts work. A stark contrast to many scientists for whom fulfilling broader impacts is intimidating or may feel like a chore.

For Karlstrom and Nadkarni broader impacts work emerged from an integrated identity; it served them both professionally and personally. They were both able to build partnerships to pave their way to success. They also played the long game, starting modestly and building from small-scale early successes. In this way, they managed to avoid the piecemeal effect of disjointed broader impacts projects that do not strategically connect with a scientist's research, or with their emerging professional impact identity. Scientists like the two highlighted here serve as the inspiration for developing the concept of an impact identity. In the following section we elaborate on the concept, its elements, and processes scientists can use to develop their impact identities.

4.3 Unveiling impact identity: from exploration to action plan

In 2012, various universities were embarking on processes to identify the specific tools and supports scientists and engineers need to effectively design, implement, and evaluate quality broader impacts. Eventually forming the National Alliance for Broader Impacts (NABI), with funding from NSF, this community now has nearly 700 members who collectively are refining practices that aid scientists in their broader impacts work (Risien, 2018). Despite increasing resources, such as training and broader impacts offices, many scientists still tend to rely on limited networks and processes to develop their broader impacts while feeling underprepared to expand or improve their broader impacts work (NABI, 2018; Risien & Falk, 2013). Nonetheless, demand for broader impacts support is on the rise and professionals who support broader impacts receive frequent requests for "just in time consulting" to help scientists develop broader impacts plans for proposals. This practice can bolster quality of broader impacts plans by connecting researchers to partners and often well-established and adequately evaluated programs to fulfill proposal requirement. However, this approach also positions the principal investigator as a passive actor who outsources broader impact work in order to concentrate on the research aspect of their grant. All too often, this represents a missed opportunity to cultivate skills and align the nature of their research, personal interests, strengths, and institutional capacities with broader impacts. While ad-hoc solutions to broader impacts fulfillment can have positive outcomes, we argue that a more

systematic approach lies in deeper engagement of the researchers themselves. Unveiling and nurturing scientists' impact identity is a critical component of a broader impacts strategy.

"Unveiling your impact identity: fueling your passions and mapping your assets" was a workshop. It was developed to help scientists: 1) explore the many dimensions that together make up their "impact identity"; 2) establish career-long impact goals; 3) identify personal and professional assets that support those goals; and 4) develop a plan to cultivate a toolset to achieve those goals over the long-term. In order to explore these four goals, participating scientists listed scientific issues and research questions about which they feel passionate. Then they recall the point in time when their decision to pursue a career in science was clear, but still unadulterated by concerns of publication rates and career advancement. Next, participants consider the multidimensionality of their own identities, including, but not limited to their identity as researchers, communicators, citizens, as educators, inventors, family members, hobbyists, etc. Identifying one's various self-concepts expands the scientists' frame of reference about skills, interests, and capacities beyond their focused area of research. The various dimensions of identity are examined in order to find connections between research interests and other parts of the scientist's personal experiences. This approach is based on studies which show that scientists are best able to conduct public outreach when they align their (scientific) agendas with expectations of prospective audiences, are part of a systematic effort to reach audiences, receive training and support, and can build off of initial investments in outreach activities (Selvakumar & Storksdieck, 2013; Storksdieck et al., 2017).

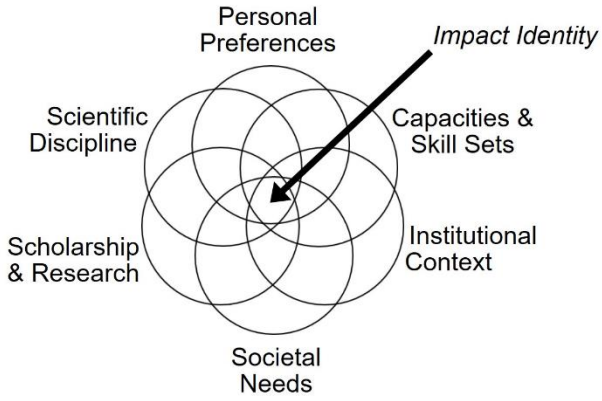

Figure 4.1. Multiple aspects and contexts of an integrated impact identity.

The deep-dive into impact identity includes five critical elements, each described below, that participating scientists explore with their participating peers.

(1) Personal identities and intrinsic motivators make up the personal preference dimension. Are you a parent, musician, minority woman in science? Do you enjoy working with children, youth or adults? Do you see yourself as communicator, teacher or inventor? Are you an activist, environmentalist, engaged in civic action?

(2) Individuals have certain capacities and skill sets that are somewhat innate or have been cultivated over time, and can guide the type of public engagement that might most suitably fit with a scientist's personally traits and interests. Are you a patient listener? Are you equipped to work with underserved audiences? Do you engage well with children? Are you an introvert or an extrovert? Can you explain your research to lay audiences?

(3) One's approach to research and scholarship adds a dimension that is deeply connected to the everyday professional practice of scientists. Through broader impacts, scholarship often expands beyond the boundaries of a discipline or the

core of a research portfolio. What is the nature of your research? What instrumentation do you use? How applied, practical, or theoretical is your research? What are the links between your research topic and potential applications? How might your broader impacts work open new dimensions of scholarship? To what degree might connections outside your circle of disciplinary colleagues support your career trajectory?

(4) Institutions also have identities and scientists do their work within the context of the institutions they inhabit. To what degree does your institution appreciate, support, and reward investments into broader impacts work? Does your institution have a public service or outreach mission? How is your institution connected to various local or regional communities? What kind of infrastructure exists through your institution to support what type of broader impact efforts (e.g. office of commercialization; institutional connection to local schools or science museums; public speaker or science café/pub series; opportunities to influence policies, legislation or regulations; etc.)?

(5) Disciplines of science are a major contributor to scientists' professional identities. Affinity with and connection among a disciplinary group is often a prominent dimension of identity. What critical questions drive your discipline? To what degree are fundamentals of your discipline already part of a K-16 curriculum? What are norms within your disciplinary society around broader impact work? How do your successful colleagues conduct their broader impacts?

We posit that ideal impact identity sits at intersection of these dimensions (see Figure 4.1). As part of creating a personal impact plan for their research, participants in the workshop explore, discuss, and record the various areas of overlap between these five key dimensions of identity to hone in on their individual impact identity. An important sixth dimension accounts for known or perceived societal needs. Researchers are encouraged to think broadly about the societal benefits of their particular research, acknowledging that not all research portfolios easily translate into direct benefits beyond contributions to the scientific knowledge base.

Broadly speaking, researchers explore three basic questions through the workshop. Examining the overlap between discipline and societal needs leads to the question: *why or what about my research may be of interest to anyone outside a group of my scientific peers?* In the long run, an engaged scientist may ask: *what should or could I focus my research on such that it does benefit society?* Exploring the intersection of personal preferences and capacities, researchers can ask the question: *what would I love to do that I am also well-equipped to do?*

These, or related questions, allow researchers to explore options for impact work that align many dimensions of their identity and acknowledge the contexts within which the scientist operates. This systematic approach builds on the nature of the particular research and discipline. It takes into account the interests and perspectives of target audiences, whether those are peers, policy makers, regulators, product developers, a science-attentive public, citizen scientists, schoolchildren, teachers, or interpreters and educators at science museums or other informal science learning settings (Storksdieck et al., 2016). Scientists ultimately can use a series of inquiries and reflections about the intersections of the dimensions of identity to build an action plan. Scientists use an action plan to articulate how they will cultivate the skills, programs, people, and relationships needed to reach impact-related goals and define concrete steps that foster the development and growth of a career-long trajectory that integrates the needs of science with the needs of society. Designed to help scientists focus their broader impacts work, this approach integrates the intellectual merit and broader impacts of their life's work. It offers an opportunity to establish career-long goals concerning scientific and societal impacts, identify personal and professional assets that support those goals, and learn to cultivate a toolset to achieve those goals over the long-term.

4.4 Discussion

Universities, science centers, professional associations, and community organizations are actively developing systems to support scientists in their efforts to strengthen the societal benefits of their research (NABI, 2018; Risien, 2017; Risien & Goldstein, 2018; Risien & Nilson, 2018a). Ad-hoc activities to fulfill broader impacts requirements are being replaced

by systematic approaches supported by an emerging university infrastructure and a class of support professionals who specialize in helping scientists fulfill broader impacts requirements. They engage researchers in professional learning that goes beyond outsourcing broader impacts and instead aims at changing capacity and attitudes to help researchers gain a new identity for providing broader societal benefits that emerge from their scientific endeavors (Risien, 2018).

Science is an evolving profession and perceptions in the scientific community about professional practice are changing over time. Early career scientists, including graduate students and postdocs, are reportedly enthusiastic and place more value on broader impacts activities (Risien & Falk, 2013; Risien & Nilson, 2018a; Storksdieck et al., 2017). This emerging openness to reaching beyond peers as the sole audiences of one's research activities is developing in parallel with other shifts in norms of the scientific community. For instance, over the last two decades, the advent of team science has shifted interdisciplinary and transdisciplinary science from a novelty to accepted practice (NRC, 2015). Similarly, scientists who engage the public, once looked upon with suspicion by their peers, are increasingly applauded for strengthening the link between the research enterprise and society (Lohwater & Storksdieck, 2017). Scientists who are successful in their discipline *and* achieve notable societal impacts have three things in common. First, they blend disciplinary strength and passion with a deep conviction and commitment to broader societal impacts. Second, they draw on a rich set of partnerships that enable them to engage in practices likely to have meaningful impacts. Finally, their professional identity expands well beyond their discipline or the confines of their research topic. They are able to knit together disciplinary ties, personal relationships, intellectual contributions, and passion for science along with their other interests and strengths to achieve meaningful impacts.

The concepts described above in the process of unveiling one's impact identity have been applied in a handful of workshops of varying length. Evaluations of workshops indicate that researchers experience immediate value, including reduced fear and confusion about broader impacts requirements, expanded understanding of possible broader impacts activities, and excitement for developing a broader impacts trajectory that resonates with

them both personally and professionally. There is much to learn about the potential of this systematic identity-based approach. Additional tests of the concepts, iterations of workshop design, formative assessment, and a longitudinal study of participating scientists can contribute to better understanding about the benefits of the approach and help to guide investments of researcher time and institutional resources. We hypothesize that using impact identities as a central organizing principle in developing career-long broader impacts yields benefits to scientists, the public audiences they engage, and enables one to strategically build on modest beginnings of broader impacts efforts.

Enthusiasm for engaging with broader impacts, increased desire for integrating work and life, and a drive to gain competitive advantage in the funding landscape may predispose early career scientists for maximum benefit from impact identity work. However, reports from the NABI community confirm that seasoned scientists are increasingly working to integrate broader impacts into their professional portfolios as well, and may also benefit from dedicated time to unveil their own impact identities, if only to become more deliberate mentors to their younger colleagues.

The NABI community has embraced the concept of impact identity in the trainings they provide to researchers and the professionals that support them. Social science research on NABI as a community has revealed critical practices, which include helping scientists in engaging non-peers in their research, helping scientists imagine ways in which their research supports broader societal goals, and brokering relationships and partnerships required to conduct broader impacts activities aligned with societal needs (Risien, 2018). Trained to think within a scientific discipline, and subject to processes of reward and recognition that prioritize research outputs, scientists develop strong disciplinary identities that can isolate them from other sectors of society. Such isolation may stymy development of the skills and partnerships needed to generate a meaningful broader impacts portfolio. This can lead to the common stereotype that the only thing that matters in science is full dedication to research itself, at the expense of all other considerations. The scientific community is fighting this stereotype since it is seen as a barrier to attracting or retaining talent uninterested in a unidimensional identity, as researcher for research sake, and instead prefers to express a

multi-faceted identity and incorporate strong societal connections in their professional lives (Eccles & Wigfield, 2002; Stylinski et al., 2018). At the same time, this stereotype is still part of the lived experience of far too many graduate students, postdocs, and other emerging scientists (Risien & Nilson, 2018a).

Retaining scientists from underrepresented groups in an effort to broaden participation and productivity of science will require many systemic shifts. Approaching this work from a place that recognizes the importance of allowing individuals to develop an identity as scholar and citizen will tap into ongoing efforts to improve conditions for underrepresented scientists. Programs like NSF ADVANCE prioritize work-life integration, and universities are beginning to hire faculty with position descriptions that explicitly support public engagement. Departments across many universities are already updating their promotion and tenure guidelines to more meaningfully include and assess public engagement (Risien & Nilson, 2018a). Consequently, we posit that widespread adoption of the concept of impact identity may have implications for the recruitment and retention of a more diverse range of scientist, and ultimately serve as a practical tool to address long-standing concerns about a better integration of science into society (Hockfield, 2018; Holt, 2018; Weingart & Lentsch, 2008).

4.5 Conclusion

Just as the boundaries between science and society change, identities are malleable and can shift. They evolve alongside changing norms of conduct and transforming expectations around what counts as success in science. We propose that unveiling impact identities, articulating impact specific goals, and developing long-term plans are critical to broader impacts success and for a satisfying career as a scientist. This entails integrating the many dimensions of a scientist's identity and the many contexts within which scientists conduct their work: their personal preferences, skills and abilities; disciplinary affordances and scholarship; institutional homes and the communities they are part of all shape how researchers position their science within and outside of academe. The use of impact identity as a framing concept for professional development holds promise to improve the reach and

effectiveness of institutional infrastructures and professional support systems that work to better connect science and society.

5 CONCLUSION

> *Change is subtle, agglomerative, often subterranean and heterogeneous. It spreads like a patch of oil. Change takes place by variations, restless expansion, opportunistic conquests, sudden captures and offshoots. ... [Change] is also multiple, unending and unexpectedly other. There is no unitary point to serve as a natural pivot for constructing subject and object, for drawing boundaries that define inside and outside and that distinguish 'macro' from 'micro'... Instead, multiplicities have only densities, determinations and lines of connections which ripple outwards.*
>
> *Robert Chia on rhizomics and the nature of change (1999 pp. 222-223).*

The sentiments above are rooted in Deleuzian geophilosophy (Bonta & Proveti, 2004; Deleuze & Guattari,1987) and provide a processual view of change. Antithetical to how we generally regard stable states as the norm and change as the anomaly, this view guided the research design and analysis herein. Network researchers and practitioners may find this case study useful to shift thinking about multi-scalar and multi-sited change from something to *do* to a process that can be guided. A model of rebellion from path dependence, the rhizome is a useful analogy for considering the role of learning networks in enabling change across macro *and* micro scales. Like the rhizome, learning networks challenge the system; they push on norms, rules, bureaucracies, and actors in habitus (Bourdieu, 1985) that constrain transformation.

While transformative learning networks lack a clear recipe for success, they embrace a set of principles critical for facing our current and future complex challenges. They have fluid boundaries and a loose and light structure. They foster learning and innovation without prescribing practice. These networks challenge our generally parsimonious paradigms of change. They refuse to lend themselves to simple metrics and measures of accomplishment, nor do they offer credit to singular powerful change makers. Learning networks have the potential to disrupt and reinvent systems that no longer serve solutions for societies most pressing and wicked challenges.

Examining boundary dynamics of these networks forces the researcher to grapple with the intricately layered structures and the nuanced relational and social dynamics in which networks operate. In this dissertation, I seek to better understand and disentangle the complexity of a social system to uncover the processes that underlie systemic change. Although, as Bergson states, "all real change is indivisible change" (1992 p. 146), there is a need for analytical distinction between structures and agents, micro and macro, and one moment in time to the next (Archer, 2010). The "breaking up of change into states enables us to act upon things, and it is useful in a practical sense to be interested in states rather than in the change itself" (Bergson, p.146). Ultimately, the process of researching transformation necessarily simplifies it. Our ability to explain systems fully is constrained by the limits of language and observation. It is incumbent on the researcher to walk a fine line between reductionism and the ineffable nature of complex systems. I have taken on the task of disentangling strands of process enough to contribute to theory and describe practice, but with regard for the complexity of the whole system.

I am optimistic that the theory and perspectives herein can elevate thinking, network design, and practice to guide transformation. These are processes in which movement toward and away from the desired path are both possible (Lopez & Potter, 2005). The difference between the two directions is subtle and depends on structures, but also the aggregate actions and decisions of many unseen actors. In rhizomic terms, their work is subterranean and difficult to observe. Each network participant is working in their own context of structures, histories, and cultures and within constraints of position, resources, and social standing. Bound by a rich context, they also bring incredible stamina for experimentation and variety of innovations into the network. The result of this loose an open network approach is that members can find alignment across sites and collaborate when and where joint efforts are likely to be most fruitful. Considerable occasions to share local work through the network provides most newcomers the opportunity to learn from other members, but also the space to make their own contributions to the collective knowledgeability. Members grapple with challenges at their own institutions, but all the while the can draw support and learn about potential solutions from their network interactions. To complete the cycle, members share

their struggles and successes with network. Together the network members discover ways to work through the non-linear, and at times agonizingly slow and confusing, processes of change. The cycle appears to progressively strengthen individual and collective work.

The chapters of this dissertation offer theory, practice, and a path forward. They are tied together by the consistent use of a boundaries lens and specific regard for how a transformative learning network may support emergent and systemic change across sites and scales. Networks are the topic of much study across disciplines including organizational studies, environmental studies, and education. However, there are few examples of in-depth study of networks that examine the specific processes, rather than conditions or actions, that support transformative capacity.

Several burgeoning sub disciplines – such as transitions and transformation, collaborative governance and collaborative planning, social innovations and social movements, social network analysis, critical management studies and change management – explicitly address change and transformation. Each group of scholars aim to create a new branch of research with a clear genealogy of theory and method. By necessity, these scholars work to distinguish their sub-disciplines and build their own boundaries to establish authority in the academic space. Staying within such boundaries provides disciplinary cover for academicians experimenting in relatively new and unstable paradigms. Development of these new domains reduces academic isolation too, but it may also prevent researchers from keeping an open mind and benefiting from the variety of ideas across disciplines.

The interdisciplinary, and admittedly eclectic, collection herein does not easily subscribe to any of these sub-disciplines. My priority and entry point was to understand the role of a network in transformational change. The suite of social theory, practical work, and philosophy that guided research design and analysis came about through exhaustive review of many literatures that could serve to ground my study. This approach provided an opportunity to immerse in the richness of many disciplines and fully embrace an interpretive approach to understand the case study with all its complexities and nuance. On the other hand, the approach leaves the work without an obvious disciplinary home, and without a built-in academic audience. My intention is to overcome this limitation by making the theory

accessible through interdisciplinary literature and connecting directly with network practitioners who can use this dissertation to guide understand their own decisions of practice.

5.1 Illuminating Boundaries

With a focus on boundaries, it is appropriate that this contribution lies in the boundaries of my own complex landscape of practice. It builds knowledge within and across three types of boundaries: 1) across many scholarly disciplines; 2) between network research and network practice; and 3) between actions of individuals and the structure of collectives. As such, I have constructed conceptual bridges. For instance, I bring together boundary concepts across science studies and social learning theory. The seminal work by Gieryn (1983, 1995, 1999) from science studies describes boundary work as "strategic practical action" and the power and purpose of boundaries in establishing authority in a domain (1983, p. 23). Gieryn does point out the shifting nature of boundaries, further developed by several scholars in and beyond the science studies arena (Abbot, 1995, 1998; Ibarra, 1999; Lamont & Molnár, 2002). Such ideas about the fluidity of boundaries are ripe for connection with the recent *Landscapes of Practice* conceptual framework put forward by social learning theorists Wenger-Trayner and Wenger-Trayner (2015). The pair emphasize that boundaries distinguish between practices of the many communities in a complex landscape. They view boundaries as "learning assets" or places in a landscape where the knowledge resources from a multiplicity of communities converge, "rich with new insights, radical innovation, and great progress" (p. 17).

In the boundaries literature some scholars privilege the powerful role of boundaries in distinguishing between social groups, or even as tools of oppression (Lamont & Molnár, 2002; Tajfel, 1982). Others emphasized how boundaries support heterogeneity and therefore learning, innovation (Wenger-Trayner E. & Wenger-Trayner B., 2015), and "socio-spatial expansion" (Engeström, 2009). These two sides present striking similarity to the long-standing debate about the causal primacy of structures versus agents in social systems. When ideas about the important role of structures are balanced with and understanding of the power of human agents, we can gain a more complete framework for scholarship about

transformation (Sewell, 1992). Accordingly, I do not give primacy to the causal role of boundary building over boundary navigation. Instead, I consider the ways in which evidence from the case reveals the tension and interdependence of building and navigating boundaries. This tension and interdependence are fundamental to Chapters Two and Three.

Boundaries are also important in Chapter Four, which highlights that the social boundaries between science and other sectors of society may be strengthening as we observe the politicization of science and perceived increase in anti-science sentiment (Hockfield, 2018; Holt, 2018). The boundary phenomenon also plays out at the individual level. For example, scientists tend to disaggregate all the parts of their identities. While usually an unconscious act, a unidimensional experience of the scientist supports false boundaries that distinguish science as impersonal and objective. The non-human view of the scientists reduces the effectiveness of attempts to engage the public in science (Scheufele, 2013). Chapter Four considers how scientist may work towards integrating the many dimensions of their identities. We argue that the process can help scientists break down boundaries and find common ground with others to improve interactions and ultimately connections between science and society.

5.2 Summary of Contribution

In the collection of manuscripts that make up this dissertation, I expand theory and offer insights for practice. The morphogenic meso-theory describes a productive tension between learning and influence in transformative learning networks. This theory may help network actors to understand how dynamic management of boundaries, shifting emphasis between strength and fluidity, can support change across scales. Such an approach can provide balance to a growing network encouraging leaders to attend to both expansion of knowledge resources and increasing network authority and influence in the system. Leaders do not need to choose a boundary strategy that is either open or closed. I claim a more dynamic approach has distinct advantages, in terms of transformative network capacity, over more simplistic attempts to make change through bottom-up coalitions or top-down managed approaches.

This work does not explain how the network moves the system from one static state to another. I rather explain a process of development where, as the network grows so too does the tension between boundary navigation and boundary building supporting learning and authority respectively. Such dynamism may not be manageable over time. As networks mature, they may need to shift focus to clearly articulate boundaries and secure a more enduring position of authority in the system. Such an emphasis on boundary building is likely to come at the cost of innovation and inclusion (supported by boundary navigation), but for potential payoffs of a strong organizational identity. Longer-term study of multiple transformative learning networks can shed light on the full lifecycle of networks to help practitioners understand promising strategies for sustainability, fundamental transition, or intentional network conclusion.

Another goal was to offer both conceptual and specific case-derived insights for practice. I uncover and describe the many varied practices, micro-practices, roles, and substructures that together establish learning networks as a force for multi-scalar and multi-sited change. My examination of practices are specifically inspired by the emphasis of many scholars on the often subtle and unrecognizable practices of enablers, who are critical guides of transformation (Chia, 1999, 2014; Tsokus & Chia, 2002; Wenger-Trayner, E. & Wenger-Trayner, B. 2015; Wenger, Trayner & de Latt, 2011).

This look at practice is not meant to prescribe a set of best practices, but to offer a reasoned set principles and options for consideration. For example, in Chapter Three I detail "building community" as a suite of common network practices. I break it down by identifying who (experts) takes on this responsibility of building community. Using evidence from the case, I provide several examples that explain the micro practices that support community building. One specific example describes how experts empower other members (sojourners) to act as ambassadors for the network. Offering such explicit examples from the case evidence paints a richer picture and provides practitioners a road map for the activities that have helped NABI create a positive environment on the path to transformation.

Practitioners can weave practices detailed here together with their own experiences to apply these examples in ways that work in their own context. The practice-oriented work

highlights that multiple substructures and a variety of practices performed by actors in different roles are interconnected and contribute to the overall transformative potential of a learning network. Network leaders should avoid prioritizing specific structures, roles, or practices and instead embrace complexity mindful that all structures and actors all have a role to play toward systemic change.

Chapter Four tracks one, of many possible, strand of transformation as it moves from individual sites, improves within the network, and then expands beyond the network. Integrated impact identity stems from the idea of supporting scientists to expand their self-concept and bring their whole selves, including the many communities of which they are a part, into their broader impacts work. The intent of developing impact identity is to reverse the perception of broader impacts as a burden to one of opportunity. The thesis is that such integration improves outcomes for scientists and the communities they engage. On my own campus, I took on the role of helping scientists imagine broader impacts that allow them to express who they are, with all their multiplicities of identity, so they may find connection with communities outside of their scientific discipline. This is work I conducted in my own sojourner role within NABI.

Without the network, impact identity may have been a short-lived approach at a single site. Similar ideas may have emerged and found varying degrees of purchase at other sites too. However, I brought the idea of impact identity to the network in 2015. I asked for, and received substantive feedback from network participants and found alignment with ideas brewing at other sites. I worked with leadership in an expert role to understand how scientists' self-concept was a constraint in the overall system. Over time, the idea percolated through the network and was evolved through network interactions and experimentation. Broader impact identity became part of the vernacular in the network. Impact identity began to appear in the broader impacts support services and trainings across sites. The concept became a sort of shared intellectual property of the network as it was integrated into practice across sites. Leadership in NABI started receiving requests for cross-site visits that included impact identity training. The concept also appeared in meetings with the NSF and other stakeholders, evidence of how the ideas of the network expand to other communities.

Impact identity is an idea that emerged from individual participants, evolves through sharing within the network, and propagates through the practices of members across sites. It demonstrates how structures, roles, and practices all play a part in morphogenesis. For university scientists, exposing the non-science aspects of their identity is non-normative behavior. The learning network collaboratively innovated to find ways to support scientists in changing their own behaviors. The idea spread across sites and generated new pathways for actors in the system to support change. Impact identity is a case study within a case study that details one of many ongoing and possible processes for tipping the system into elaboration. Other case within case examples include the use of development and broad, but individualized, tools like broader impacts menus, broader impacts training for early career faculty, or strategies that improve the way scientists address broadening participation of underrepresented groups in science through broader impacts.

5.3 Future Applications

There are many applications for this work. I describe some ways in which network evaluators, planners, or leaders may apply these insights to their own practice. I also identify some specific research trajectories and potential collaborations that can build directly on the findings herein. I have already found application for these findings in my own professional practice and intend to build on it in future efforts to apply transformative learning network principles of practice to efforts that better integrate science and society.

The theoretical perspectives embedded here may be useful to network designers and evaluators as conceptual framing to establish an initial theory of change. Tension between boundary building and boundary navigation can aid in understanding network elasticity and how leaders work to balance and modulate between supporting learning and gaining the influence needed for collective action. The morphogenic lens can help network leaders and developmental evaluators in understanding change processes in the context of complex systems. For example, simply conceptualizing change as a process that can be guided, but not something to achieve, can assist evaluators in establishing benchmarks that realistically represent network progress and avoid false claims of linear cause and effect.

The various network substructures and practices of experts and sojourners may contribute to design of evaluation protocols to assess actions across sites and scales. The typology, and recognition of many concurrent phenomena in transformative learning networks, provides a roadmap for embedded or developmental evaluation (Patton, 2011) approaches. Inclusive of the presented case evidence, this work shines a light on an expanded and rich set of possible substructures, practices, and roles for network leaders to consider cultivating. Any given network can ask themselves, are we supporting a broad variety of practices that meet the needs of individual sites? Are we sufficiently maintaining or expressing boundaries in ways that support our influence over policy? Are we keeping our network open enough to foster learning and innovation?

This study may provide productive framing for deeper study of similar networks. In particular, NSF Research Coordination Networks, the mechanism that established NABI. According to the NSF solicitation, such networks should, "advance a field or create new directions in research or education by supporting groups of investigators to communicate and coordinate". This dissertation can be used to frame a multi-case longitudinal study to compare and contrast multiple leadership and network design strategies, and to understand the merits of each in terms of transformative capacity. A multi-case study could also be used to understand the lifecycle of such networks. Understanding how the networks emerge, how they progress, and what they eventually become could provide valuable insight into the long-term potential of such networks.

The processual approach may also be applied to understand how the recently NSF-funded alliances to support inclusion and equity in science are supporting learning and collective actions in the space. Many of these alliances are designed using the collective impact framework (Kania & Kramer, 2011). The prescriptive and simplistic framework provides clear ingredients for collective action (common agenda, shared measurement, mutually reinforcing activities, continuous communication, and a backbone organizations), but these ingredients do not address the complexity of processes and practices across scales. This study provides the scaffolding for such a design.

While I have viewed NABI as a mechanism for improving the connections between science and society, higher education is the social-educational system that serves as the backdrop for the network. Other scholars have identified the important role of boundary spanners and enabling actors in higher education reform networks (Hill, 2016; Kezar & Gehrke, 2016). Many such networked efforts are underway (the Network of STEM Education Centers; the Center for the Integration of Research, Teaching and Learning; the Accelerating Systemic Change Network; and the Association of American Universities STEM Education Initiative). While much education research has an interventionist tilt, design-based implementation research (Penuel, Fishman, Cheng, & Sabelli, 2011; Fishman, Penuel, Allen, & Cheng, 2013) is also a prominent approach, and some are highlighting the nuances and social aspects of change in higher education (Beach, Sorcinelli, Austin, & Rivard, 2016; Kezar, 2013). The processual approach in this study can inform collaboration with several scholars in the higher education reform space (see several articles in review by Kezar & Gehrke, 2018; and scholars in the Accelerating Systemic Change Network).

While I primarily focus on transformation via learning networks in this dissertation, it is also a deep examination into the people, institutions, and collective efforts operating at the interface of science and society. A significant shift in our social-political landscape occurred over the course of this project and there are concerns about the long-term implications of this shift for the place of science in society (Hockfield, 2018; Holt, 2018). Perceptions about where science sits within, or outside of, society are shifting too. Although public trust in science as an enterprise has remained relatively stable over the last decades (AAA&S, 2018), it may be too low for science to play an appropriately proportionate role in understanding and testing solutions for our educational and environmental challenges. Here, I aim to enhance understanding of how networked approaches may improve our ability to integrate science and the solutions it offers as critical to overcoming society's most intractable challenges.

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