

# Essential tensions in interdisciplinary scholarship: navigating challenges in affect, epistemologies, and structure in environment–society research centers

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**Abstract** Scholars have enumerated unique challenges to collaborative interdisciplinary research, many of which evade prescriptive solutions. Some of these challenges can be understood as “essential tensions,” necessary and persistent contradictory imperatives in the scientific process. Drawing from interviews with internationally renowned interdisciplinary environment–society research center leaders primarily located in United States academic institutions, we identified three hierarchical tensions in collaborative interdisciplinary research: (1) an epistemic tension between knowledge generation processes that blend multiple approaches into one unified intellectual perspective versus pluralistic processes that maintain multiple, discrete intellectual perspectives, (2) a structural tension between organizations that provide stability to persist and build unified knowledge, while maintaining the flexibility to experiment with novel organizational arrangements that foster innovation, and (3) “affective” tensions for individual researchers between the security of working within cohesive research communities versus attraction to the creative challenges in new intellectual communities. Our results indicate that these tensions are interdependent, similar to previous observations that disciplinary and interdisciplinary knowledge productions are linked. Rather than attempt to resolve tensions between dueling directives, leaders of interdisciplinary research centers can manage essential tensions with purpose through process-oriented and self-reflective management of the unique epistemic culture of the research centers they lead.

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## Introduction

Challenges in facilitating interdisciplinary research within society–environment studies and other domains have given rise to “how to” guides that enumerate best practices and guiding principles (NSF 2004). Yet, there are challenges in interdisciplinary research that evade “how to” prescriptions and one-size-fits-all solutions, as evidenced by the diverse array of context-specific approaches deployed by interdisciplinary research teams and centers (Klein 2010). Crosscutting each unique research experience is a persistent tension: interdisciplinary research teams and centers often position themselves as something new and different from the traditional discipline, but as time goes on, there are processes that work to pull the new novel organization toward the very kind of disciplinary structure from which it separated.

This tension is best understood within Kuhn’s (1977) framework of “essential tensions” through which he shows that both convergent and divergent thought are contradictory imperatives for scientific progress. Kuhn elaborates that science needs both research that converges around a set of frameworks, methods, and theories—normal science—to achieve scientific consensus as well as disruptions that challenge fundamental assumptions in order to innovate. This essential tension also emerges in collaborative science, but, as Hackett (2005: 788) explains, essential tensions are “...not pathologies, but the inherent and enduring tensions that confront every research group [...]” What makes them essential is that, when presented with these tensions, evidently the “group’s direction and fate are shaped by the choices it makes” (Hackett 2005: 788). Interdisciplinary endeavors add an additional layer of tension to the collaborative process between the search for, “novel insights of an interdisciplinary nature and the need for established intellectual doctrines founded in the classical disciplines” (Anderson 2013: 3).

This research deploys the essential tensions framework to cast light on inherent dualisms between disciplinary and interdisciplinary scholarship. The research asks: how do leaders of interdisciplinary organizations navigate these dualisms? Drawing from 18 interviews with leaders of interdisciplinary society–environment research centers affiliated with Arizona State University, the Resilience Alliance, and other institutions in the USA and elsewhere, we consider how interdisciplinary collaboration leads to essential tensions in (1) epistemic approaches to knowledge generation, (2) structuring of institutions in support of research endeavors, and (3) the affective, or emotional, disposition of individual scholars.

## Literature review

Interdisciplinary collaborative research in society–environment research

Klein (1990: 11) observed a “subtle restructuring of knowledge in the late 20th century” in which scholars deployed a “new division of intellectual labor, collaborative studies, [and] increased borrowing across disciplines” called interdisciplinarity. In the years since Klein’s

observation, the interdisciplinary restructuring of the academy has gained momentum, fueled by the creation of interdisciplinary research centers in universities and National Science Foundation (NSF) funding directives (Sá 2008). Dubbed “Mode 2,” this restructuring of knowledge production replaced an older model, which was predominately disciplinary, hierarchical, and supported by autonomous scientists and institutions (Nowotny et al. 2003). Despite what some view as mixed results, and despite critiques leveled against the effectiveness of interdisciplinary research centers, “Mode 2” knowledge production persists (Rhoten 2005; Hackett and Rhoten 2009; Jacobs and Frickel 2009).

The interdisciplinary turn has been particularly prominent in research domains bearing integrative labels such as human–environmental interactions, social-ecological systems, and sustainability science. These fields are referred subsequently as society–environment research; any research domain concerning the interrelationship between humans and the biophysical realm. Scholars in these fields argue that although the processes of refinement and generalization of knowledge that created disciplinary departments have historically been productive, it is exactly these attributes that disconnect individual disciplines from the complex and complicated “real-world” challenges of the twenty-first century (Lubchenco 1998). This claim is based on the notion that disciplines are relatively unified, insular, and static; however, it is worth noting that many disciplines, such as geography, are inherently pluralist. Furthermore, disciplines do evolve over time: splitting into sub-disciplines that cross-pollinate and re-aggregate (Abbott 2001). The distinction between disciplines and interdisciplinarity has blurred with the rise of “interdisciplines,” which are formal and informal non-traditional communities of scholars (Stichweh 1992). Nevertheless, in society–environment fields, there is a pervasive opinion (c.f. Kates et al. 2001) that interdisciplinary studies are necessary to solve the kind of “real-world” challenges Lubchenco identifies.

The interdisciplinary turn is evidenced by the proliferation of interdisciplinary environment science research centers, NSF’s Coupled Human-Natural Systems funding line, and international research networks such as International Geosphere-Biosphere Programme (IGBP), International Human Dimensions Programme (IHDP), and many more. The most recent iteration of these international society–environment research networks, Future Earth, lists as its first objective: “increased collaboration between disciplines and knowledge domains” (ICSU 2014: 1). These directives for society–environment research reflect what is sometimes referred to as “Mode 2” knowledge production in that they are application oriented, transdisciplinary, and reflexive. However, mechanisms for quality control such as peer review and national quality assessments, particularly outside of the USA, reinforce traditional disciplinary trajectories (Nowotny et al. 2003; Woelert and Millar 2013). In the wake of large interdisciplinary momentum and sometimes under conditions that favor disciplinary orientations, many scholars have taken pause to reflect on the task of doing integrative research; especially with concern about a perceived gap between the rhetoric of interdisciplinarity as a catalyst for change and the reality of doing interdisciplinary research within existing academic structures (Klein 2010). Research on interdisciplinary processes has focused on challenges, the bulk of which fall broadly into three categories: issues for individuals operating within disciplinary-oriented university structures, problems encountered in interdisciplinary teams during the collaborative process, and navigating national research governance directives (cf. Felt et al. 2012; Nistor et al. 2014, Woelert and Millar 2013). Various strategies at university institutions have been proposed and deployed, such as establishing research centers, providing grant incentives, reorganizing curriculum, and reimagining faculty recruitment and evaluation processes (Sá 2008; Holley 2009).

For individual scholars, the most frequently cited barriers to interdisciplinary collaboration are structural challenges arising from an academic rewards system that favors disciplinary over interdisciplinary work in promotion and tenure review criteria (NSF 2004). Additionally, the quality of new, interdisciplinary journals may be uncertain—a challenge that some predicted would dissipate over time—may still be a persistent issue, particularly for early career scholars (Clark 1996; Daily and Ehrlich 1999; Campbell 2005). These constraints mean that it is particularly difficult for early career scholars to engage in interdisciplinary collaborations (Felt et al. 2012; Gewin 2014).

Structural barriers to interdisciplinarity extend to undergraduate and graduate training as well (Graybill et al. 2005; Newswander and Borrego 2009). One study found that the efficacy of training programs such as the NSF Integrative Graduate Education and Research Traineeship (NSF-IGERT) in preparing students for interdisciplinary collaboration beyond that of traditional graduate training is ambiguous (Hackett and Rhoten 2009). Frequently cited challenges for interdisciplinary team collaborations include practical concerns such as “language barriers” that create confusion about the meaning of terms and broader issues such as integrating among epistemological and ontological differences (Redman et al. 2006; Bracken and Oughton 2006). More specifically, social and physical science integration issues may arise from a lack of precedents for integration or context-specific constraints (Sievanen et al. 2012). Integration issues also arise when integrating “constructivist,” social science approaches, with “positivist,” physical science frames. For instance, Petts et al. (2008) note that social scientists feel pressure to privilege positivist frames of inquiry in interdisciplinary collaborations, especially when the goal of collaboration is presented as providing hard data for solving “real-world problems,” because social science findings were viewed (in some case still are viewed) by physical scientists as “soft science,” arbitrary, or little more than common knowledge. Finally, there may be a gap between the way interdisciplinary research is conceptualized in national research directives and the capacity to fund and evaluate the quality of the work as an integrated whole using systems established with traditional disciplines in mind (Nowotny et al. 2003; Woelert and Millar 2013). In sum, interdisciplinarity creates challenges at different scales for individuals and teams of researchers, departmental and university conventions, and more fundamental issues relating to truth-seeking in science.

### Conceptual approaches to the study of interdisciplinary collaboration

Several concepts from the sociology of science are particularly helpful in untangling the interrelated nature of individual, institutional, and epistemic challenges to interdisciplinary research. For instance, scientific research takes shape in particular settings and determines how research is framed, methodologies are developed, and knowledge is verified. Knorr-Cetina (1999) described this scientific process as the formulation of epistemic cultures in which “those amalgams of arrangements and mechanisms—bonded through affinity, necessity, and historical coincidence—which, in a given field or subfield, make up how we know what we know...that create and warrant knowledge,” (Knorr-Cetina 1999: 1). Understanding the diverse epistemic cultures of science involves, therefore, “relocating culture in the micropractices of laboratories and other bounded habitats of knowledge practice” (Knorr-Cetina 2007: 1). In short, the way in which scientific knowledge is produced and validated is manufactured through the everyday practices of individuals in particular places repeated and reinforced over time. At a broader scale, national discourse about the type of knowledge universities ought to produce may influence the conditions for university operations, leading to multiple knowledge regimes internationally (Bleiklie and

Byrkjeflot 2002; Bliedie 2005). Knorr-Cetina's (1999), (2007) observations suggest that individual, institutional, and truth-seeking challenges to interdisciplinary collaboration may be indelibly linked.

If institutions, individuals, and epistemic approaches to interdisciplinary collaboration are interlinked, then changes to one will likely have implications for the others. For instance, establishing interdisciplinary institutional structures, especially creating research centers, is a common strategy for addressing institutional conflicts between interdisciplinary activities and department structures. Academic structures, however, often follow a trajectory termed “institutional isomorphism,” through which academic institutions mimic one another's structure and procedures to maintain legitimacy (Stensaker and Norgård 2001; Frank and Gabler 2006). These institutional frameworks may be pragmatic for legitimizing interdisciplinary scholarship; however, they also “route communication inward” by limiting intellectual engagement to units such as departments or schools (Jacobs and Frickel 2009: 47). Therefore, while it may be possible to overcome institutional and individual challenges through institutional isomorphism, doing so in a way that mimics disciplinary departments may create a unified epistemic community that lacks the intellectual diversity often sought in interdisciplinary collaboration.

Novel institutional structures can also be devised that re-imagine the process of collaboration and avoid the pitfalls of institutional isomorphism. For instance, “boundary organizations” are places where sustained, meaningful interactions between stakeholders and scientists are purported to produce more credible, salient, and socially relevant knowledge (Star and Griesemer 1989; Guston 2001; Cash et al. 2003; Parker and Crona 2012). Boundary organizations were conceived of as a way to reconcile the legitimacy of science—which traditionally has been done by separating scientists from non-sciences—while recognizing the key role of stakeholder input in solving important problems. Each stakeholder group retains its primary identity as either stakeholder or scientist by meeting in a neutral territory, often with neutral facilitators, and discussing a problem domain using “boundary objects,” such as maps, models, or charts that serve as an entre point for discussion. For example, scientists may meet with policy makers to parameterize climate scenarios to provide a plausible range of future conditions and provide data in a format (e.g., timescale, recognizing jurisdictional boundaries) compatible with decision-making institutions.

Jacobs and Frickel (2009) characterized interdisciplinary research centers at universities as boundary organizations due to their position within the university structure but beyond the normal territory of departments. Similar to boundary organizations, interdisciplinary research centers could galvanize the expertise of diverse scholars without converging toward a shared or unified epistemic community (cf. pluralism and consilience in the subsequent section). Yet, boundary organizations create new challenges for individual scholars. In these “hybrid spaces,” researchers become “boundary brokers” taking on different identities and accountabilities (Parker and Crona 2012; Bozeman and Boardman 2007; Miller 2001). Individual scholars may experience “role strain” due to the varying expectations placed upon them concerning their disciplinary depth versus their interdisciplinary breadth, long-term versus real-time knowledge production, basic versus applied research objectives, and academic autonomy versus practitioner consultancy (Parker and Crona 2012). Furthermore, once novel structures such as boundary organizations have begun to proliferate—especially through the NSF-funded Decision Making Under Uncertainty and NOAA Regional Integrated Sciences Assessment—they follow processes that look very much like institutional isomorphism, but align with national research directives.

In the absence of novel or conventional institutional structures to support interdisciplinary collaboration, some scholars have described the emergence of “coherent groups,” small and tightly linked groups of researchers, united in opposition to current intellectual trends (Griffith and Mullins 1972). In this context, interdisciplinary research agendas may emerge as a kind of new social movement, wherein groups pursue research in resistance to a constraining disciplinary status quo (Frickel and Gross 2005).

The emergence of coherent groups and social movements supports observations that there is an affective, or socio-emotional, dimension to the practice of science. Individual scholars thrive intellectually in environments in which they feel confident and supported, and thus capable of managing the culture of organized skepticism (e.g., scrutiny of scientific claims) in academia (Merton 1973; Parker and Hackett 2012). Coherent groups, however, are susceptible to inward communication routing if they become exclusive to a small subset of individuals. Therefore, while individual emotional security may facilitate epistemological freedom, attending to those emotional needs by limiting intellectual interactions to a small group of like-minded individuals can also lead to unified and sometimes closed knowledge paths.

### Essential tensions: a dialectic approach

The trade-offs involved in resolving individual, institutional, and epistemic challenges to interdisciplinary research constitute essential tensions, paradoxes in the scientific process that evade clear-cut solutions. Kuhn (1977) used the essential tensions framing as a way to understand the social production of science. He argued that scientific discovery required processes of convergence, through which knowledge is refined, as well as processes of divergence, in which convention is challenged and opportunities for innovation are opened. These tensions cannot be resolved through compromise, and they are not considered flaws detrimental to the scientific project. The indispensable nature of each approach to the scientific project and the degree of influence they exert in determining the direction of the scientific project as researchers choose to navigate them, however, make these tensions essential.

Hackett (2005) identified essential tensions that arise in laboratory research where individual researchers take on dual, and sometimes conflicting, personas as autonomous scholars and as laboratory team members. This environment produces tensions in identity, control, and risk. Identity is the tension between group goals versus individual needs; control is the tension of maintaining “on-the-bench” lab skills versus doing the necessarily distancing “articulation work” of management; and risk is the fear of failure in pursuing risky, innovative research versus the threat of obscurity in safer, routine research. Scholars engaging interdisciplinary collaborations may encounter similar essential tensions because it also involves a high degree of collaborative work among scholars with diverse intellectual perspectives at many different stages of their careers. Anderson (2013) convincingly argues that interdisciplinary collaboration intensifies previously identified essential tensions through the introduction of epistemic diversity. This amplified tension manifests as a pull between individual intellectual independence and the epistemic dependence of the group as well as between organized skepticism that ensures academic rigor and the need for intellectual trust among group members with differing expertise.

Philosophers of science distinguish processes of convergence that move toward a “synoptic,” “comprehensive,” or unified, set of theories, methods, and epistemology from those processes that move toward a diversity of cognitive maps in knowledge construction (Klein 1990). Epistemic unity is closely related to, but distinct from the idea of a discipline

because the disciplines may fall within a spectrum of more pluralistic disciplines (e.g., geography) or unified ones. This distinction has been applied to the process of bringing together of multiple epistemic communities in interdisciplinary collaborations.

Miller et al. (2008) argue that epistemological pluralism—the view that multiple, distinct cognitive maps, knowledge structures, and norms are valid and each should be accommodated and not compromised—leads to more robust knowledge than consilience, where multiple, independent knowledge systems converge upon a single unified truth. Epistemological pluralism maintains the interdisciplinary process by retaining the fundamental ingredients of interdisciplinary research: the coexistence of distinct cognitive maps with the capacity to collide intermittently and recede relatively unscathed as new research agendas emerge over time. In this case, each way of knowing comes to the table to inform the other, although the actual presentation is typically anchored in one explanatory perspective. Consilience, however, permits permanent intermixing of cognitive maps, as once independent knowledge systems converge upon unified truths. The collisions of cognitive maps that are widely separated, or even contradictory (e.g., positivism and constructivism), however, have proved to be particularly problematic (Petrie 1976). The emergence of epistemic cultures may be inevitable as well because individuals operate in the “machinery” of the interdisciplinary organization and, over time, some degree of blending in cognitive maps are likely to occur.

Building on these insights, we assert that interdisciplinary collaborations that bring together cognitively disparate knowledge systems amplify essential tensions in team science. Specifically, we examine three new sets of tensions (Table 1): epistemic, as individuals and organizations oscillate between pluralism and unity; structural, as groups adopt novel organizational structures that provide the flexibility to accommodate a plurality of perspectives versus attempting to retain the stability found in established institutions like disciplinary departments; affect, as individuals pursue the lure of creative challenge when engaging with scholars from different, but complementary, disciplinary backgrounds versus the pull toward the comfort of a unified academic community. These additional tensions are born from the inherent duality between the traditional role of the discipline—

**Table 1** Essential tensions analytic framework

Tension	Description
<i>Epistemic</i>	
Pluralism	Interdisciplinary research, usually problem oriented, in which the original disciplines are retained
Unity	Interdisciplinary research with shared approaches, frameworks, and methods that is “proto-disciplinary” in that it may lead to new disciplines
<i>Structural</i>	
Flexibility	Institutional design to that is adaptable, capable of evolving, and embraces new, innovative approaches
Stability	Institutional design that provides continuity and conforms to existing expectations within the academe
<i>Affective</i>	
Comfort	Individual scholars’ need for emotional support and risk reduction in research and career development
Challenge	Individual scholars’ drive to explore new intellectual territories and high-risk, potentially high-reward domains



to unify and refine a set of theories, methods, and approaches to knowledge generation—and interdisciplinary collaboration, which depends on the interactions between a multiplicity of knowledge domains. The ways that directors, administrators, and other leaders navigate these challenges, therefore, shape the direction and fate of their interdisciplinary organization.

## Methods

We interviewed program directors ( $n = 18$ ) of interdisciplinary research centers with substantial impact in their organization's respective field. Respondents each described their experiences as interdisciplinary scholars, the history of their research center, and challenges and strategies for maintaining their organizations. The respondents were selected using an opportunistic sample of Arizona State University (ASU) faculty, visiting lecturers to ASU, attendants of the 2011 Resilience Conference at ASU, and the 2012 Facilitating Interdisciplinary Research and Education (FIRE) Conference at the University of Colorado, Boulder. While most interviews were conducted at the ASU campus, only three ( $n = 3$ ) respondents were members of the ASU faculty or administration. Respondents' home institutions were research-intensive public and private universities in the USA ( $n = 13$ ) and international locations ( $n = 5$ ) [Canada ( $n = 1$ ), the UK ( $n = 1$ ), France ( $n = 1$ ), Sweden ( $n = 1$ ), and Australia ( $n = 1$ )]. Research domains spanned the sciences and the humanities, including sustainability science ( $n = 10$ ), environmental science ( $n = 4$ ), physical sciences ( $n = 3$ ), and biomedical research ( $n = 1$ ). Semi-structured interviews were conducted in person ( $n = 14$ ) and over the phone ( $n = 4$ ) between March 4 and June 8, 2011. We conducted semi-structured interviews that lasted between 25 and 82 min and were organized around key themes including the research center's history, objectives, visions of interdisciplinarity, main challenges and successes encountered, trade-offs experienced by its members, and strategies employed to manage those trade-offs. Interviews were recorded, transcribed, and analyzed by each member of the research team. The analysis was conducted in an iterative manner whereby each member of our team inductively coded all interviews using NVivo 10 (NVivo 2011) and identified themes. The themes were then collectively compared and discussed by the research team in a series of workshops held in Spring and Fall 2012 to assemble a set of common overarching themes. These final overarching themes are presented in the results section along with illustrative quotes.

## Results

### Epistemic pluralism and unity

Respondents described the two epistemic models for interdisciplinary collaboration described in the literature. The first model, epistemic pluralism in which the original disciplines are retained, was often linked to research teams or centers dedicated to solving a specific problem or addressing a particular problem domain (e.g., sustainability). The second model, epistemic unity, involved integrating existing disciplines to fill gaps between them. One respondent described the second variation as, “proto-disciplinary, in the sense that if it succeeds it becomes essentially a discipline: biochemistry, astrophysics.” Most respondents subscribed to the first model and expressed an aversion to



interdisciplinary approaches that might lead to new disciplines. A respondent explains this aversion using a hypothetical environmental sustainability department as an example:

If we concede that the environment is anti-disciplinary then we have to account for where disciplines come from. They come from trying to get your head around something and in the process you wind up in a place where you're specialized so you can't possibly get your head around it. You are forced to be interdisciplinary...There's an advantage of a department of sustainability studies. It brings together a bunch of specialists and they are all interested in sustainability and maybe they'll learn each other's languages and the graduate students will meet one another. But to imagine that there is a discipline, a particular cannon of knowledge that is sustainability, would be hubris.

Creating new disciplines out of interdisciplinary knowledge domains is a paradox to the interdisciplinary project. Interdisciplinary knowledge domains can fall into a familiar process through which novel mixtures of disciplines coalesce, become epistemologically unified, and begin to resemble the very disciplinary structures from which they originally departed.

Our respondents recognized that maintaining epistemological plurality and avoiding “disciplining” created a tension with scientific truth-seeking processes. Without the structure of disciplines, one respondent pondered, “How do you build cumulatively?” and concluded that the answer was not to, “assume that institutional permanence is the answer to that question.” Another respondent agreed: “I think that a much better model is one in which you build institutions which can evolve into different combinations of disciplines as the world changes.” Charting this course created a unique set of challenges as one respondent observed:

How do you give enough stability and yet keep it dynamic. You are always walking that edge. And if you go too far in either direction, its either going to become stultified, ossified, and awful in that way or everybody is going to be afraid and it is going to be in chaos and you are going to throw the baby out with the bathwater.

This respondent articulates two sets of challenges that emerged in creating interdisciplinary organization that supported epistemic pluralism: structural and affective. Such organizations have dueling directives to invigorate collaboration through flexible arrangements that are capable of evolving, while also garnering stability through more conventional organizational structures, such as departments. The flexibility and stability of an organization was linked to the challenges individual scholars faced when they left the security of a disciplinary community and joined the uncertainty of intellectual experiment in an interdisciplinary organization.

#### Institutions: flexibility and stability

As leaders of interdisciplinary research centers, our respondents described different strategies for providing flexibility and stability and how these strategies depend on the particular political-academic context of each university. A prime concern was devising ways to embed flexibility in the university structure that conventional departments could not provide. Arizona State University (ASU) combined departments into larger interdisciplinary schools. This sweeping restructuring was possible, in part, due to the relatively weak bureaucratic legacy of ASU compared to older, more established public and private universities elsewhere in the USA and abroad. Further, in the ASU model, resources are

centralized and allocated to university initiatives that closely match the new interdisciplinary focus. There are limitations to a purely top-down model of instituting interdisciplinarity. “If somebody on top has no idea what’s good and what ought to be kept and what ought to be destroyed,” said one researcher at a different university of the ASU model, “It’s not right.” In other words, a top-down approach requires exceptional vision at the top as well as feedback mechanisms signaling the robustness of the decisions regarding direction and allocation of resources. Respondents noted that flexibility is achieved by giving individual scholars the resources they need and a high degree of independence. This independence is supported by flexibility in the promotion and tenure process at the administrative level. A senior administrator explains, “We have no collective expectations. If you are a faculty member working here as an assistant professor you would have the unique trajectory that you are on.” These comments about intellectual independence underscore the point that the intellectual drive to engage in collaborative interdisciplinary research is catalyzed by top-down administrative support to leverage university resources and build momentum through interdisciplinary hires, but ultimately requires buy-in from the researchers themselves.

Imbedding flexibility into what was often characterized a “rigid” university bureaucratic structure was particularly challenging in long-standing, public and private universities with established traditions, and reputations developed around the German disciplinary model. Because the disciplines and administration are so closely linked at universities with long-standing bureaucracies, interdisciplinarity in such institutions occurred in research centers that operated independently from departments. Research centers offer distance from the disciplinary focus of departments; however, a respondent from Harvard explains that they are still a relatively rigid structure at his institution:

The centers by and large don’t actually do innovative stuff. What they do is provide the incubators for programs. Programs are a thing smaller than a center. Where they have their adaptability is layered down at the level of programs.

The hierarchical model described by the respondent is a strategy for tending to the dueling directive to provide institutional stability, which is done through the relatively permanent structure of centers, and flexibility, which is achieved through incubator programs.

The role of bottom-up, faculty-driven processes in fostering interdisciplinary collaborations was particularly critical at institutions that did not have the structures to support top-down restructuring. Examples include smaller, long-standing universities in the United States and Canadian universities. A respondent from Princeton University explained the importance of teaching:

Princeton is a small place and we are not going to be the Broad Institute or Washington University or something like that, we are not on the right scale for that...If you put a group of full-professors from seven different departments in one building there is absolutely no guarantee that they will work together, let alone talk to each other on a regular basis unless you give them something else to do that is a joint endeavor and that of course is the teaching.

At Stanford University, another long-standing institution, interdisciplinary collaboration preceded the establishment of a research center. A respondent described, “Stanford is a small place and everybody knew each other...We had this whole bottom-up voice of faculty and students from around the university wanting this stuff, doing this stuff themselves.” She goes on to concede the importance of support from the top, but qualifies, “it doesn’t take much because in our case, it just came down to people being interested in

wanting to talk together for a long period of time.” In the case of both Princeton and Stanford, interdisciplinary collaboration was faculty driven, with support from the administration. A respondent from the University of British Columbia (UBC) explained how interdisciplinarity could not be directed, managed, or controlled from the top-down but rather fostered through a horizontal integration of faculty and university managers working on academic and operational sustainability. Indeed, respondents noted that bottom-up processes at these institutions were still susceptible to becoming rigid, over time. The respondent from Stanford noted the importance of, “mid-stream corrections,” explaining, “One of the most critical things for the Institute is to be very introspective and to have mechanisms to evolve.”

An increasingly pervasive strategy for conducting interdisciplinary research is to operate outside the university system in international consortiums such as the International Geosphere-Biosphere Programme (IGBP) or the International Human Dimensions Programme (IHDP) on Global Environmental Change. The Resilience Alliance (RA), for example, a major interdisciplinary research program, was organized as a non-profit. RA network representatives come from universities, government, and non-government organizations internationally. This independent status gives the RA a choice in their own policies and organizational structure, and a high degree of flexibility to change those policies and structures over time. The RA did create their own journal, *Ecology and Society*, a home for intellectual discourse on resilience theory and a convenient place for its members to meet publication requirements for promotion and tenure. Independent status also made the RA especially dependent on grant agencies; which meant they lost a lot of funding during the financial crises in 2008. One independent choice the RA made was to limit membership to 15 to encourage “small group synergies.” Our respondent echoed findings by Parker and Hackett (2012) that this presented a challenge of appearing “elitist” when the group became more established and scholars wanted to join. The small group synergy also potentially entrenched a particular mode of thinking. He explained, “We are re-thinking how we are going to do all of this now because you don’t want to get stuck in some kind of rigid bureaucracy, so we let it evolve.”

Some respondents noted that occasional failure was an inevitable outcome of experimenting with novel institutional structures. A researcher at a private university, for instance, likened interdisciplinary research centers to start-up companies. In this formulation, failure and success are closely linked, “precisely one of the arguments why [the USA] generate[s] more start-up [companies] and more successful start-ups than many other places is because we have vastly higher rates of failure...” Failure, however, can be costly in terms of funding, reputation, obligation to the public, and, perhaps most acutely, to the professional life of individual scholars.

Affect: comfort in community and create challenge

Interdisciplinary scholars proceed with both the risk of working outside of the established intellectual disciplines and the allure of novel research. Most academic work is fraught with emotional challenges, due to uncertain research outcomes and the high levels of peer criticism directed at the results of that research. Academia, therefore, can engender a kind of self-doubt that interdisciplinary research can amplify. A respondent explained: “Personally, I think the biggest cost this kind of work imposes on the people who are doing it is that it drastically exacerbates the normal feelings of inadequacy and incompetence that any serious researcher [feels].” He goes on to describe how this same uncertainty about academic rigor is problematic for the peer review process: “It’s not just that doing good work

is hard, it's [that] recognizing good research reliably is even harder." A scholar in a traditional discipline, for instance, may be reassured of their worth by publishing in flagship journals or receiving honors from national societies, which others in the discipline would recognize as noteworthy achievements. A disciplinary community, therefore, makes it easier to identify good research through established metrics and benchmarks of success that also offer some academic and personal reassurance for both the reviewer and the reviewed.

Establishing an academic identity is crucial for individuals—this is particularly so for early career scholars seeking academic jobs, promotion, and tenure—yet identity may be fluid and relative to the context of scholarly engagement (e.g., disciplinary versus interdisciplinary) (Abbott 2001). Yet interdisciplinary scholars find themselves casting multiple academic identities. A respondent in the field of ecology explained, "In a traditional Biology department I was basically considered a broad generalist. I came [to the interdisciplinary research center] as one of the only ecologists...and immediately went from being labeled a generalist to being labeled a specialist." This respondent, a senior scholar, describes two academic identities, generalist and specialist, that are not only predicated on his position within a disciplinary versus interdisciplinary setting, but also seemingly contradictory. For junior scholars, occupying too many intellectual spaces may be a challenge, as a respondent details, "You've got to get out [of graduate school] in time and you need to come out with a really coherent dissertation on a single thing. Unless we re-imagine the academy a graduate student can't be trained to be interdisciplinary." Many respondents concurred, adding that promotion and tenure processes were a lingering challenge. As one respondent said succinctly, "If you are working in an area where there's nobody out there who knows what you are doing, you won't get tenure." Some disciplines, however, were recognized as being inherently plural broadly focused. In these disciplines, such as geography, interdisciplinarity was not likely to be "punished" in the way respondents described above.

There are risks to doing interdisciplinary research, but the reward of creative challenge compels some scholars to do interdisciplinary research. Interdisciplinary researchers, in fact, were variously described as a "self-sorting bunch," attracted to "messy," "fuzzy," and "chaotic" environments. They tend to be interested in reimagining or enlarging the problem setting. As one respondent said, "I like walking the line...it makes life interesting." Another respondent concurred, "It can be very uncomfortable because you are outside of your deep knowledge area, which is part of the fun."

Ph.D. training, promotion, and tenure often give individual scholars a sense of authority in their field, but interdisciplinary collaboration often requires disciplinary authorities to become students in a new field of inquiry. Interdisciplinary scholars, one respondent noted, "Need to have an open mind because working interdisciplinarily is more of a challenge than staying in your comfort zone, [and] sometimes people do not have the patience for it." Tolerance, it seems, and a shared willingness to learn from one another is essential to successful interdisciplinary collaboration. One respondent experienced this tolerance during a collaborative meeting with a researcher from a different field: "I could ask questions...that were really dumb from the point of view of somebody in her discipline. But she never laughed at me and she never put me down."

Scholars articulated ways to build new kinds of communities that can provide the support associated with disciplinary departments. These new communities are built through formal and informal opportunities to meet and engage with like-minded scholars, and ultimately to develop trust. One respondent explained that she and her team created a physical space in her organization that was welcoming: "There are lots of different places

that people can sit down and talk. And there is a living room, there's a kitchen, there's a library upstairs." This setting helped researchers have small, intimate talks where they could not only work out intellectual ideas but also get to know one another. Others described the role of informal social activities such as field trips, happy hours, and other informal activities that led to discussions of novel research ideas.

Ultimately, community building requires sustained interactions among individuals to build a sense of cohesion, process that can also lead to a shared language. The values of pluralism that persist in many interdisciplinary organizations may conflict with the seemingly disciplinary project of establishing language norms. One respondent warned that interdisciplinary leaders should never simply "assume things are fine in these unusual institutional spaces. They take constant care and attention and feeding and so on: nurturing."

Individuals also must make occasional returns to their disciplinary roots to maintain depth in their original field. Keeping this depth therefore allows scholars to bring their disciplinary specialty to bear in interdisciplinary collaboration. As one respondent reflected on this challenge, "You advance a common objective and sometimes you forget your discipline." The challenge, therefore, for an individual scholar, is to keep the interdisciplinary and disciplinary projects working in an iterative relationship. Hopefully, this generates new research ideas while building individual skills such as patience and a willingness to be uncomfortable.

## Discussion and conclusion

Using the essential tensions framework highlighted the ways in which tensions that are known to be present in scientific research—epistemic, structural, and affective—are manifest in interdisciplinary collaborative research. Respondents articulated a preference for epistemic pluralism, which was associated with innovation, but also acknowledged that epistemic unity was necessary at times to move knowledge forward. Disciplines were almost always characterized as unified entities, with the exception of geography, which was described as being more plural, encompassing both the natural and social sciences. Similarly, respondents detailed strategies to embed flexibility in relatively rigid university structures to allow novel collaborative processes to be supported, while at the same time creating mechanisms to provide the stability required to capture resources for research activities, establish legitimacy, and to ensure that members had the means (e.g., promotion and tenure review processes, publication outlets) to achieve promotion and tenure. Finally, our respondents thought that interdisciplinarity attracted scholars that liked intellectual risk taking, but articulated strategies for fostering comfortable academic community, which was often described as a prerequisite for and venturing into new and uncomfortable intellectual territories and providing a sense of security that their intellectual contributions were worthwhile.

Our interviews also point to considerable interplay between epistemic, structural, and affective dimensions of academic work. For instance, many respondents favored epistemic pluralism to unity, and institutional arrangements that were flexible and capable of evolving were devised, and a large degree of intellectual independence for individual scholars (e.g., they retain their disciplinary expertise) was often recommended to foster it. Flexibility and independence, however, ran counter to structural need for institutional stability to maintain high-level research programs and scholars affective needs for intellectual community. For example, the case-by-case promotions and tenure standards at ASU

increases structural flexibility in the review process, but also may increase anxieties about meeting expectations for promotion and tenure among individual scholars that lack other models to which they can compare their own personal trajectory. To counter the “chaos” and “uncertainty” of structural flexibility and individual independence, a process similar to institutional isomorphism may occur, whereby interdisciplinary research centers adopted practices that mimicked those of disciplines. A good example of this is the RA establishing its own publication outlet or teaching interdisciplinary courses based out of the research center. Similarly, the quality of interdisciplinary work may be difficult to judge, provoking individual anxieties about intellectual authority and self-worth and structural challenges in the peer review process (e.g., how do others assess the quality of work?). Creating a new, interdisciplinary community through formal and informal interactions can create shared meanings, methods, and approaches through which to assess work quality. Yet, there was a constant worry that these practices would, as Jacobs and Frickel (2009: 47) articulated, “route communication inward” and a desire for organizations to evolve and for individual scholars to return to their respective disciplines. This interplay—and the tendency toward epistemic unity—may be evidence of Knorr-Cetina’s “epistemic cultures,” which are generated through the “micropractices” of the collaborative processes in each interdisciplinary research center.

Although respondents felt that disciplines were insufficient to address complex society–environment problems, they did not believe that interdisciplinary research collaborations should replace disciplines. Rather, the irony is that interdisciplinary scholarship needs disciplines as counter-point (Abbott 2001; Klein 2000). Without the discipline there would be no conversation, no back-and-forth between equally valid epistemologies that are the essence of the dialectic. Interdisciplinary leaders, therefore, were always in reflective conversation: with the members of their organizations, with themselves, and with this essential tension within the entire project. Our interviews were limited to senior scholars who were not only intellectual leaders in their fields, but also leaders in internationally reputable society–environment research centers that many would deem “successful” examples of interdisciplinary collaboration. This bias in the sample means that the plight of fledgling institutions and early career scholars may be diminished in our findings. We also did not see evidence of role strain for scholars seeking to maintain both disciplinary and interdisciplinary identities, most likely because our respondents were well established in their respective fields before embarking on interdisciplinary research trajectories. Instances of failure to create structures to foster collaborative interdisciplinary research may also be under-represented. Finally, we did not see instances of militant strategies, such as the formation of coherent groups or social movements on campus, because, despite large challenges, most universities were receptive to these reputable interdisciplinary research centers. While beyond the scope of this research, the experiences of young scholars and fledgling research centers merit further consideration, especially as interdisciplinarity continues to expand in society–environment research domains.

This study examined research centers focused on society–environment themes, but epistemic, structural, and affective tensions likely extend to any interdisciplinary or problem-driven research center because the tensions are ultimately connected to the process of bringing together scholars with diverse frameworks, theories, methods, and professional obligations (e.g., promotion and tenure standards). Although leadership styles are ultimately tied to particular contexts, a general quality of good leadership is the capacity to anticipate future conditions, both good and bad, in order to ready their organization for opportunities and challenges (Bainbridge 2012). Based on our analysis, leaders of interdisciplinary and problem-oriented research centers can anticipate tensions, for instance,

acknowledging when interdisciplinary research becomes unified and injecting plurality through restructuring or new membership to foster both generalizable knowledge generation and innovation. Leaders can also anticipate that decisions that chart course in one tension domain (e.g., epistemic, structural, and affective) will likely also alter course in another domain. For example, the RA made the decision to limit membership (structure) in order to foster small group comfort (affect) and strengthen theory (epistemic unity). The leaders further anticipated the need for restructuring in the future (e.g., new members, new organizational structure) in order to inject new, innovative ideas (epistemic pluralism) into resilience theory. Finally, many leaders noted the need to recognize and support bottom-up, faculty-driven processes. Despite the claim of a shift away from unified and static thought, disciplinary journals, departments, and degrees have considerable momentum, and interdisciplinary organizations often find themselves relying on these familiar conventions to gain legitimacy and standing in the academy. Yet, leaders of interdisciplinary research centers are decision-makers that can chart a course with intention. They can make decisions to protect pluralism with flexible arrangements and attracting academic risk takers, while at times providing stability and direction for the organization and fostering an academic community for members. This is possible because this essential tension is not something to be avoided as pathology, but embraced as necessary dialectic in the advancement of interdisciplinary research.

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