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Article

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Abstract: Sustainability science seeks to identify and implement workable solutions to complex problems. This transdisciplinary approach advances a commitment to work across boundaries that occur among individuals, disciplines, and institutions to build capacities for informed and innovative decision making in the face of uncertainty and change. The concept of boundary work and related discussions of boundary objects and organizations are important, expanding focal areas within sustainability science. While communication is described as central to boundary work, insights from the field of communication have largely yet to inform theorizing about boundaries within sustainability science. In this paper, we highlight three communication perspectives, namely media studies, collaboration and partnerships, and systems theories, which are particularly relevant for understanding how boundaries form, the social context in which boundary work occurs, and informed strategies for enhanced boundary spanning and management. We use three case studies to illustrate how communication theories and methods provide dynamic and strategic lenses within transdisciplinary processes to enable collaborators to build capacity for change, sustain critical and reflective inquiry, and approach difference as generative in collective efforts to produce sustainability.

1. Introduction

Research in the field of sustainability science has committed significant attention to the issue of boundaries [1,2], primarily focusing on the relationship between science and policy [3,4]. However, boundary work extends more broadly "to the activities of those seeking to mediate between knowledge and action" [1] across social domains. These may include boundaries among scientists and journalists [5], academic disciplines [6], communities and universities [7,8], and governing bodies [9] among others. Working across disciplines and institutions, spurring innovation in higher education and communities, and encouraging flexibility and cross-scale collaborations in governing bodies are key goals in sustainability science and in related discussions of transdisciplinarity [10–12]. These goals require that we address the myriad boundaries among individuals and institutions. Communication studies have important contributions to make to sustainability science, especially in managing complex boundary processes [13].

In this essay, we draw from communication studies to address the concept of boundaries within sustainability science [1]. We see communication as a context-dependent concept that refers broadly to strategic, substantial, and dynamic interactions among humans and environments [14]. Importantly, we do not define communication as one thing or another but as a dynamic way to understand multiple levels of experience [14]. This definition of communication corresponds with sustainability science's commitment that boundary work be sensitive to context [1]. Boundary work, including boundary spanning and management, the use of boundary objects, and the role of boundary organizations, occurs through communication. Communication within boundary work looks quite different depending on the context in which it occurs. For example, an analysis of the types of words and sources journalists use when describing science-related stories is a different communication context than one where scientists and citizens meet in the same room to make decisions about stormwater management or where people in different disciplines attempt to conduct research together. Communication theories can help us explain the boundaries that emerge at different levels of experience in media, public participation, and systems contexts respectively.

We argue that interdisciplinary orientations to communication, including media studies [15], collaboration and partnerships [16], and systems theories [17,18] offer theoretical and methodological tools for attending to boundaries. While sustainability science clearly focuses on boundaries, the field needs to expand its discussion of communication–related dimensions. We know from sustainability science that boundary work occurs at interfaces, but what are those interfaces and how do boundaries emerge? How do communication theories and methods help describe context and identify appropriate strategies relevant for boundary work? Following Curran [19], this is an effort to "wrap our brains" around the concept of boundaries through multiple communication perspectives, each of which provides a unique lens on boundaries.

We briefly review the concept of boundaries within sustainability science, focusing on the core concepts of boundary work including (1) boundary spanning and management; (2) boundary objects; and (3) boundary organizations [1]. We then consider these facets of boundaries through three communication traditions introduced above. These literatures contribute to and expand on theorizing about boundaries by introducing a focus on communication within the multiple aspects of boundary work. In each section, we draw from a brief case study to set the preceding discussion of communication and boundary in a particular example within sustainability science. As Scholz *et al.* [20] demonstrate, "case studies, and in particular transdisciplinary case study (TCS), are a powerful tool for teaching and research on complex environmental problems to conduct individual, organizational, and societal sustainability learning." We take our case studies from Maine's Sustainability Solutions Initiative (SSI), a statewide sustainability science program based at the University of Maine Orono in which the authors participated on interdisciplinary teams as social scientists and communication scholars. This organization provides a rich case study for the concept of boundaries because it has worked to address boundaries among disciplines, institutions, and communities since the inception of the project in 2009. Interdisciplinary teams of university faculty created one of the first Boundary Spanning courses in the United States and another course designed around the theme of stakeholder–researcher boundaries. Communication theory and methodology helped advance SSI's understanding of boundaries. This essay highlights orientations that sustainability organizations might use as they consider boundaries through multiple lenses. We conclude with a call for more efforts like the one occurring within the University of Maine system in which multiple institutions intend to build and improve relationships among science and society. We take up the concept of transdisciplinarity, one that we find threaded into discussions of sustainability science [12], because this lens offers well-developed yet flexible frameworks to organize our discussion [10,11]. Our conclusion offers a transdisciplinary process orientation and key questions to illustrate how communication can describe and produce context and encourage strategies for reflective, equitable, and sustained problem solving [21].

2. Boundaries Defined in Sustainability Science

A transdisciplinary endeavor, sustainability science seeks to bring research to engage "wicked problems" that occur at the intersections of society, ecology, and economy [22]. These complex Social-Ecological Systems (SES) problems are characterized by entanglements of human and non-human interests, cross-scale interactions, and indefinite stopping points and thresholds [23]. Clark and Dickson [24] describe this focus on problems addressed, as opposed to the disciplines involved, as one of sustainability science's defining characteristics. Sustainability science represents a response to the increasingly urgent call to recognize and understand these complex interlinked problems and identify novel solutions that effectively move knowledge into action [25].

Transdisciplinarity as a lens integrates with sustainability science, most notably in its engagement with complex problems through multiple forms of collaboration that seek to improve relationships between science and society [10,11,24,26]. While characterizations of transdisciplinarity vary, theorists generally describe *ideal* process phases that start with problem framing and collaborative research team formation [10,11,20]. In the first phase, collaborators direct attention to problem definition and transformation [10,11]. In the second phase, interdisciplinary integration promotes the

co-creation of solutions-driven knowledge. Importantly, integration does not refer to a blending of disciplines but rather a situation in which epistemic communities can maintain a plurality of perspectives and produce fundamentally new connections among different ways of understanding the world [6,10]. Transdisciplinarity occurs in the third phase where, through dialogue and negotiation, new knowledge and social order flow into practices and institutions in iterative cycles [10,21]. Thus, transdisciplinarity offers useful heuristics for how collaborations evolve and how attention to communication and boundaries can promote strategies for sustained and dynamic relationships among actors and institutions.

With its commitment to solving complex problems in ongoing cycles of linking knowledge and action, attention to boundaries and boundary work is essential to transdisciplinary sustainability science processes [1,25,27]. Leading theorists in sustainability science propose the following definition of boundary work:

The central idea of boundary work is that tensions arise at the interface between communities with different views of what constitutes reliable or useful knowledge. If an impermeable boundary emerges at the interface, no meaningful communication takes place across it. However, if the boundary is too porous, personal opinions mix with validated facts, science gets mixed with politics, and the special value of research-based knowledge fails to materialize [1].

Clark *et al.* [1] note that the most complex configurations of boundary work occurred when there were multiple knowledge users with sometimes conflicting reasons for using the knowledge and also when knowledge was used within negotiations. From these and other observations, they concluded that context matters and strategies should follow context.

Three key themes have emerged in the sustainability science literature on boundary work, demonstrated in Clark *et al.'s* [1] definition and elsewhere [4,28,29]. First, there is a simultaneous need for boundary spanning and management. Second, boundary objects may improve communication and help produce social order in the contexts in which they are used. Third, boundary organizations have the potential to coordinate diverse practices and needs across social domains. We expand on each of these below.

2.1. Boundary Spanning and Management

The permeability of boundaries that emerge at interfaces among individuals and institutions and the associated complexity with managing and crossing them depend on a host of interrelated factors. These complexities may include historical constructions of policy making as a linear, transfer model, the strategic absence of civil society within policy arenas, and cultural barriers between science and society [29]. As noted in Clark *et al.'s* [1] definition, the need to make boundaries more permeable is held in tension with the need to simultaneously reify boundaries to maintain the legitimacy of social activities within specific realms, most notably science and policy [30].

A primary concern in boundary management is the interface between science and policy [29,31]. Because sustainability science is concerned with applying salient, legitimate, and credible knowledge to complex decision-making processes, maintaining a boundary around science becomes paramount [32]. Coordinated boundary management activities intend to link the supply of and demand for science and preserve the role of science in knowledge production [32]. Yet, as Miller [33] highlights, the

negotiation of salience, credibility, and legitimacy has implications for how sustainability gets defined, what gets studied, and how it interacts with society. Boundary management represents a complex, dynamic, and emergent set of practices. Strategic choices about how to proceed may be informed by context-sensitive communication orientations that encourage questions and reflective analysis throughout the transdisciplinary process.

2.2. The Use of Boundary Objects

Boundary crossing aims to improve information and knowledge transfer. The use of boundary objects may help. While flexible, boundary objects can be characterized as one or more of four broad types [28]. The first of these consists of repositories or collections of physical objects. The second, ideal types, are generally diagrams, maps, and atlases in which the object is a representation taken to stand for reality but at the same time is a difference-making actor on its own [34,35]. Maps have been shown to be particularly useful boundary objects because they create a common ground of understanding from which participants may build [1]. Coincident boundaries occur where there is a shared external boundary but the internal contents may be different. An example of this is when the boundaries are drawn around a geographic area, like a state, and one group understands and describes the internal contents of that area differently than another, such as highlighting transportation networks *versus* species data. Fourth and finally, standardized forms are agreed upon methods that are used consistently across groups and geographic areas.

In one influential case study, Star and Griesemer [28] describe the use of boundary objects in methods standardization across disciplines and institutions in the development of a natural history museum. They argue that boundary objects must be "plastic enough to adapt to local needs and the constraints of the several parties employing them, yet robust enough to maintain a common identity across sites." Further boundary objects constitute a key process, not simply a fixed tangible entity, that participates in "developing and maintaining coherence across intersecting social worlds" [28]. Jahn *et al.* [10] describe how boundary objects may serve as a communication device within the early phases of collaboration to promote the transformation of the boundary object to an epistemic object. This transformation aligns with Jasanoff's [36] discussion of co-production as the simultaneous invention of knowledge and social order within the collaborative setting. The epistemic object participates in the problem definition and in the emerging social order engaged around that problem. Thus, at one level, boundary objects help coordinate a diverse assortment of practices through which a range of actors may come together to develop shared understanding. On a second level, boundary objects inhere differentially according to the situated contexts of those seeking to cross the boundary [28]. In other words, boundary objects create opportunities for individuals to communicate across differences and they are also responsive to and possibly reproduce those differences.

2.3. Boundary Organizations

Boundary spanning, management, and objects comprise a diverse array of entities and processes. Boundary organizations can help coordinate complex interactions that occur within this work. Osmond *et al.* [37] argue that boundary organizations perform at least five functions: (1) they *engage* or convene disparate groups; (2) they *exchange* by encouraging social learning and participatory

processes; (3) they *collaborate*, providing opportunities for dissimilar groups to work together; (4) they *explain*, thus providing translation between groups and helping focus the work on issues of relevance to either party; and (5) they *reward* by providing benefits to all groups involved, often helping each group understand the strengths and needs of the other players. Communication between organizations and individuals is at the heart of these functions.

Aside from facilitating collaboration, boundary organizations also participate in the production and reproduction of social order on either side of the boundary. Guston [4] explains that these organizations move across domains and, in doing so, they participate in an inherently political process in which "the politicization of science is undoubtedly a slippery slope. But so is the scientization of politics. The boundary organization does not slide down either slope because it is tethered to both, suspended by the coproduction of mutual interests." This view of boundary organizations accepts that both science and politics constitute a political process, one in which power enables ways of knowing and being in the world [33,38].

2.4. Bringing Communication to Boundaries

In sum, recognizing, understanding, and finding ways to work boundaries is central to the process of sustainability science [1,27]. A focus on spanning and management activities; the use of multiple types of boundary objects; and the development of organizations that move flexibly across boundaries can help integrate boundary work into research. But questions remain: how do we know when to span, when to manage, and if we are doing either effectively? What types of boundary objects and organizations participate and what kind of work do they do? How do we understand and make strategic decisions in the face of multiple layers of social production that occur through boundary work? Returning to Clark *et al.'s* [1] framework for boundary work and their beginning response to these questions, we note that context matters and strategies must follow context. Communication theories and methods help describe context and in turn, assist with identifying strategies and encouraging reflective awareness of their impacts.

In the following sections, we reconsider boundaries through distinct lenses in an interdisciplinary suite of communication theories, including media studies, collaboration and partnerships, and systems. We draw from sustainability science cases of vernal pool regulation, stormwater management, and collaborative lake research, each of which coheres around the theme of water. We selected water as an organizing theme because, much like the multidimensional nature of communication and boundaries, water reminds us to consider boundaries and processes of transformation that occur within dynamically linked cycles of interaction. For each case study, we provide a brief summary of the method and we highlight how the case demonstrates relevant communication theory and boundary concepts.

3. Media Analysis: Spanning Boundaries among Science, Policy, and Media

Media studies generally approach communication as a process of representation in which journalists describe issues that follow certain patterns and analyze how audiences interpret those patterns in ways that inform understanding and action [39]. A body of communication scholarship within this tradition examines the role of media framing and source use to understand the multiple influences that frames may have on audiences' understanding of an issue and who is positioned as relevant sources of

information on select topics [40,41]. Studies of media framing broadly address the types of messages and how those messages contribute to legitimated forms of knowledge and subjectivities, though not necessarily in the same studies [15]. Framing studies may focus on strategic choices to highlight certain sources of information; thematic or content related ways of organizing information; or episodic patterns in the type and frequency of certain stories [42]. In terms of boundary work, media studies largely focus on interpersonal and institutional boundaries among journalists, scientists, policy makers, and publics. In this section, we highlight how framing studies illustrate particular context characteristics in boundary spanning and management. We also discuss how media frames may operate as boundary objects, highlighting key insights from literature on framing climate change as a public health issue among other examples. Finally, we describe how training activities may help journalists, scientists, and policy makers coordinate their activities to meet multiple communication goals.

3.1. Framing and Source Use at Interfaces of Science, Policy, and Media

Communication of information through frames helps inform public agendas. How stories are told and who is cited as primary sources within media influence the kind of information that circulates within society. At the same time, these messages have social effects [43–45]. The constitutive dimension of boundary work occurs where frames and sources participate in the construction of the boundary—a boundary set around what and who is relevant, as just one example—and the ordering of science and society on either side of it.

The constitutive dimension of framing is particularly evident in media effects' focus on climate change communication. Scholars seek to understand the social impacts of climate change frames and strategic options for encouraging informed action based on known risks and uncertainty [46–49]. Researchers have found that emphasizing climate change as a public health issue promotes boundary spanning among scientists and citizens and increases the likelihood that valuable information reaches people for informed decision making [46,49]. These frames also promote spanning among diverse individuals and institutions, such as public health professionals with Centers for Disease Control and Prevention, organizations like the American Lung Association, and social justice advocates who recognize that risks are not born equally across communities [50].

Media communication about climate change is just one of many examples to demonstrate that framing is a set of practices that transcends the simple act of putting information together in understandable ways. Fully-developed frames typically perform four social functions: problem definition, causal analysis, moral judgment, and remedy promotion which all contribute to the constitution of social order [51]. McCombs and Reynolds [52] highlight how journalists and editors operate under constraints, such as limited capacity and time, and consequently some story elements have to be emphasized or over others. The result is "something like the highly limited view of the outside world available through a small window" [52]. Media studies can help illustrate how frames direct attention and guide evaluation of some issues over others and the implications of these framing practices for emergent boundaries.

The interpersonal and institutional boundaries between journalists and their sources of information are important, as this boundary spanning influences the information that appears in different types of media [53]. Gandy [54] suggests elite sources routinely supply journalists with information to ensure it

reaches specific audiences who have the ability to shape and change policy agendas. As Brown *et al.* [55] note, "by controlling the information available to these target audiences, sources are able to define decision-making options and, ultimately, to control the decision-making process." Thus, the boundary between journalists and sources becomes a valuable space for sharing information, and spanning the boundary potentially gives certain sources more power to shape debate and political outcomes.

3.2. Frames as Boundary Objects and Training for Enhanced Boundary Work

Media frames can operate as influential objects at boundaries among science, policy, and media. Nielsen [5] describes media frames as boundary objects in her analysis of the boundary between science and media in the Galathea Deep Sea Expedition in the early 1950s. In this case, both scientists and journalists used the frame of the "sea serpent." This frame operated differently on either side of the boundary, and "[perhaps] because of its uncertain and myth-like character, the sea serpent could adopt many positions, take on various meanings and fulfill different functions for the scientists, journalists, and others involved in the collective organization and management of the expedition" [5]. In its plastic continuity, the sea serpent frame served as a boundary object that maintained a distinction between science and media but also facilitated communication across the boundary. Nisbet [41] also demonstrates how frames may serve as boundary objects, without expressly using the term boundary to do so. He argues that "interpretive storylines that can be used to bring diverse audiences together on common ground, shape personal behavior, or mobilize collective action" [41]. This description corresponds to the notion of boundary objects as ideal types described above [28]. As these cases demonstrate, strategic selection of particular frames may foster the development of common understanding and shared ideas about scientifically-informed action.

The complex context in which media frames, as boundary objects, communicate messages and help create social order points towards the potential role for training to help boundary workers strategically coordinate their practices. The structured workshop series associated with the European Science Communication Network (ESConet) provides one example where scientists participated in trainings focused on conducting media interviews, writing news stories, and presenting research to legislators [56]. Qualitative evaluation of these workshops revealed that participants found them effective and the practical exercises were particularly beneficial for skill development. Similarly, Schneider [57] found that trainings for journalists can be effective, especially when these workshops include time for journalists and scientists to interact directly. Opportunities for open and reflective discussion about key science communication challenges, such as framing the concept of uncertainty, created a space for mutual learning among scientists and journalists. Understanding the strategic and dynamic boundary dimensions of framing and source use can help guide decision making about how to promote boundary spanning and management between scientists, journalists, and policy makers. The following case example provides further illustration of these dynamics and training opportunities.

3.3. Case Example: Framing and Media Training for Science-Policy Boundary Spanning in Vernal Pool Regulation

Our example addresses boundary work through a case study in which we used a media analysis and science communication training around vernal pool regulation in Maine, in the northeastern corner of

the United States. Vernal pools are small seasonal wetlands that provide essential breeding habitat for select species. For scientists who study and seek to conserve vernal pools, they offer a distinct set of challenges because they are ephemeral (they usually dry up by late summer); they exist on private property and transcend property boundaries; and people do not agree on their ecological, economic, or social values [58]. Despite these challenges, after more than a decade of collaborative work among scientists and legislators, Maine has one of the strongest examples of vernal pool legislation in the U.S. [59]. However, recent efforts in Maine's legislature have sought to roll back vernal pool regulations. In highly contested policy debates, such as the one surrounding vernal pools, it is important to understand how frames function at the boundaries among science, media, and policy and how communication training may support boundary spanning processes. We specifically highlight the role of journalists as boundary spanners, the use of frames as boundary objects, and the development of empirically based communication strategies and training for this particular context.

In our analysis, we focused on frames and the sources of information journalists used in their stories about policy debates surrounding changes to vernal pool regulation in the 2011 legislative session. We conducted an archival analysis of frames within Maine newspaper coverage of relevant vernal pool legislation during this time period. We used LexisNexis to retrieve the data with the search terms "Vernal Pools; Maine" which yielded 20 articles and 25 editorials/letters to the editor which we then coded for frames and sources.

One of our primary findings was that journalists did not use scientific data to frame their stories. Instead, they deployed political frames and largely did not include relevant scientific studies. The political frame as a boundary object influenced social perceptions of this issue and potentially ignored the scientific basis for the political decision making. We also found that journalists covering this debate largely cited political and government sources from both party affiliations. Because many of the articles covered the public hearings that accompanied the bill proposal to reverse vernal pool regulation, many business owners, non-governmental organizations (NGOs), and citizens were also quoted. Scientists were notably absent as sources, as was discussion of relevant and extensive vernal pool studies conducted within Maine [59]. These findings highlight how political figures and NGOs influence the conversation about this issue and are crossing the boundary with journalists more easily or readily than scientists or others with relevant scientific information.

These findings match the observed tendency of journalists to describe complex policy issues in ways that mirror how they would cover political stories and elections by emphasizing conflict and partisanship [60,61]. The focus in these stories follows who is winning or losing in the polls, the political tactics and strategic maneuvering, personalities of those involved, and how the issue develops in policy realms. In Maine, as across the U.S., many newspapers are losing their specialist environmental and science reporters [62]. As this occurs, journalists become less apt to frame stories in ways that help readers understand the complexity and how science as a process of inquiry helps make sense of this complexity. These trends reinforce boundaries that constrain scientific literacy [63] and democratic engagement with science in society [64].

Given that these well-established journalistic norms influence the emergence of multiple boundaries, we developed media training for individuals engaged in strategic boundary work. Based on this and previous research focused on vernal pool communication [58], we developed a media training workshop with vernal pool researchers that included opportunities to practice media

communication skills and develop targeted messages around regulatory issues [56]. We created context-dependent recommendations on how to share scientific information more readily with journalists. For example, we recommended distributing targeted factsheets to specific conservation organizations within the State, all major Maine newspapers, and legislators. We suggested that these factsheets should respond to some of the key communication issues identified in our analysis, such as providing information about relevant scientific studies to support arguments and about the potential impact of the legislation to hunting and fishing. A key next step in this effort is to develop a more extensive training program that, following Schneider's [57] example, brings scientists, journalists, and policy makers into face-to-face discussions about communication.

Media analyses' focused on frames and cited sources provide a lens to view emergent boundaries and boundary work among media, policy, and scientists and science-based institutions. Scholarship in this tradition explores the complex dynamics that influence how stories are framed and the social effects the frames produce. Bringing media studies to sustainability science helps explain some of the dynamics of boundary formation and management and reveals potential strategies to influence boundary work. In the next section, we shift from focusing on communication as a system of representation to communication as embodied within spaces of action and experience in processes of collective participation.

4. Collaboration and Partnerships

The study of communication in collaboration and partnerships seeks to understand how communication influences our ways of relating to *context-specific* social and physical worlds [65,66]. Researchers in this tradition interpret interpersonal dynamics [67], formation of identities [65,68], and issues related to empowerment and one's capacities to act and influence outcomes (agency) [16,69]. Analyzing communication patterns in collaborations can provide information about participants' knowledge, beliefs, attitudes, and perceptions and help explain group decision-making and relationships [69–72]. This tradition is particularly relevant in boundary work for considering how communication influences interpersonal relationships and how language choices guide patterns of participation. Boundary work from this perspective focuses on making participation more inclusive and equitable to facilitate spanning activities [16,73]. It also emphasizes defining legitimacy to maintain boundaries so that sustainability comes to mean certain things, like having access to clean drinking water, as opposed to other possible meanings [74]. Finally, as in the media studies tradition, this perspective offers pragmatic strategies and tools as boundary objects to coordinate the diverse activities of spanning and management [67,75,76].

4.1. Boundaries for Democratic Engagement: Participation and Legitimacy

Of particular importance to collaboration and public participation researchers is understanding whether goals of inclusiveness and democratic decision-making have been achieved. In the environmental communication literature, the integration, or lack thereof, of expert and non-expert knowledge in environmental decision-making processes has received substantial attention. Research shows that non-expert, local information is sometimes dismissed [77,78], while technical, expert knowledge is sought and privileged [79–82]. Top-down decision making processes can create

boundaries around knowledge integration in which: "impacts important to stakeholders and the polity may be ignored or that the mechanisms for assessing the magnitudes of impacts are constructed in a way that delegitimizes nonscientific constructions" [83]. A study of the controversy surrounding a hydropower project in northern India illustrates how top-down processes ignore or even exclude certain voices [84]. In this case, decision-makers primarily evaluated the project using technical criteria and they neglected to analyze many important locally relevant issues, such as how women would be differentially affected by the project and anticipated changes in access to historic grazing areas.

Senecah [16] provides a touchstone theoretical development in the concept of voice in an effort to promote inclusiveness and democratic involvement. She argues that participants must have access, standing, and influence in decision making processes. Access refers to the opportunity to express one's opinions and ideas openly and safely. Further, it means that one needs access to the necessary information to participate. Standing includes a set of actions and behaviors in collaborative or participatory environments. Some of those behaviors include active listening, opportunities for dialogue and deliberation, courtesy, and empathy, to name a few. Finally, influence means that the decision-making process used to sift through multiple and sometimes conflicting ideas is clearly laid out and accessible to participants. To understand if these goals have been achieved, one must pay attention to the boundaries (re)created through communication practices.

Cox [74] aptly points out that the boundaries of legitimacy, or the right to exercise authority, are constructed in language. He provides the example of the term "common sense." By employing this term when discussing environmental management issues, the assumption is that what is "common sense," represents things as a fixed reality. Symbolic legitimacy boundaries describe associations people attach through their language choices to specific policies or people. These symbolic boundaries create separations between types of knowledge and groups. In the context of public participation, attaching legitimacy to the technical information provided by managers and scholars in environmental disputes runs the risk of defining nontechnical information presented by citizens as illegitimate [74]. This boundary privileges one group—or one type of voice—at the expense of another group and its voice. Awareness of boundary management through communication practices is particularly important in sustainability science because of the real potential for decision-making process that are too narrowly focused or exclusionary to yield solutions that are not equitable and, therefore, not sustainable [33,85,86].

4.2. Strategies to Promote Inclusive Participation Contexts

What are some tangible, practical ways to promote inclusiveness in collaborative endeavors? What practices facilitate boundary spanning and management? Daniels and Walker's [73] Collaborative Learning Approach (CL) represents one orientation to boundary spanning. Walker *et al.* [75] argue that CL is appropriate for "natural resource, environmental, and community conflict and decision making situations with two fundamental attributes: complexity and controversy." CL "encourage[s] systems thinking, joint learning, open communication, constructive conflict management, and a focus on appropriate change" [75]. The model focuses on learning about participant values and worldviews, defining the problem, and creating alternatives and solutions. The beginning phase of this process focuses on common understanding instead of consensus. This

common understanding serves numerous benefits, including establishing a shared context from which to approach issues, while highlighting the flexibility of boundaries.

CL uses worksheets as one boundary object to promote inclusiveness and provide flexible tools. Each participant completes a worksheet and shares a report with a small group, which encourages idea sharing and helps participants "gain voice" [16,75]. This enables diverse voices to have access to the conversation, share knowledge, learn from each other, bring values and beliefs out in the open, and think systematically through a problem *as a group*. As Graham [87] argues "meanings are not static, repeatable commodities, but are negotiated as interactions unfold." CL ensures that meaning emerges through collaboration.

Delicath [88] urges practitioners to remember the importance of equipping citizens with knowledge and skills to participate effectively, but also to consider what motivates and empowers those communities and how *they* might want to participate, not only how *you* want them to participate (emphasis in original). Outside of traditional forums for public participation, communication scholars recommend exploring non-traditional boundary objects and exercises for participation, such as toxic tours for addressing environmental justice issues [69] and using cultural resources such as art, storytelling, and theatre for cultural activism around environmental controversies [88]. These alternatives are especially important for marginalized groups who may not have access to these processes or feel excluded from them.

4.3. Case Example: Boundary Work and Collaboration for Stormwater Management

This case study examined a collaborative stormwater management permitting process in which communication and boundary work were central to collaborative efforts. Stormwater pollution occurs when debris, chemicals, dirt, and other pollutants flow into waterbodies. Across the U.S., polluted stormwater runoff is a direct contributor to the approximately 40% of U.S. waterbodies which currently do not meet water quality standards [89]. Given the damaging effects of stormwater on numerous water systems, the U.S. Environmental Protection Agency (EPA) regulates its discharge. One important stormwater program in Maine is the Municipal Separate Storm Sewer System, or MS4. Through the MS4 program, the Maine Department of Environmental Protection (DEP) issues stormwater permits to municipalities to discharge stormwater to surface waterbodies in the state [90]. To meet standards required under the permit, numerous municipalities and regulated entities in Maine developed collaborations, including the Bangor Area Stormwater Group (BASWG).

Some authors on this paper collected data during participant observations at monthly BASWG meetings from spring 2010 to summer 2013, participation in BASWG education and outreach committee meetings for approximately one year, and while conducting surveys in 2011 and 2013 in collaboration with the BASWG on stormwater awareness and the outcomes of the BASWG's social marketing initiatives. We identified myriad boundaries in this collaboration. Members were asked to cross physical boundaries between municipalities; institutional boundaries among municipal and non-municipal agencies and state agencies; and disciplinary boundaries between different areas of expertise and ways of understanding stormwater management. The communication scholarship we described above helped us identify areas for improved communication, particularly in public participation. The use of boundary objects and consideration of the ways language constitutes boundaries of

legitimacy were key factors that promoted inclusive communication, built trust, and improved natural resource management.

BASWG included seven municipality and five non-municipal members; a professional facilitator; and university/college researchers and industry partners. DEP staff attended meetings, making this program unique because of the close cooperation between local and state managers in terms of crafting and implementing the regulation, showing the kind of change for which McNie [29] calls in her discussion of the historical separation of civil society, regulatory, and policy realms. This multi-stakeholder, multi-level group sought to leverage collective capacities to address the regulation requirements that each entity struggled to meet individually.

In this context, boundaries among individuals and institutions were largely managed through professional facilitation, established agendas, member access to local and state management information, public comment periods, active negotiation during meetings, and frequent opportunities for networking and interpersonal communication [75,76,]. Of particular importance was how diverse forms of knowledge and expertise were integrated into the stormwater permit, and the use of boundary objects was a frequent strategy. In stormwater management activities in Maine, the MS4 permit and public comments were particularly useful as boundary objects. There were significant discussions and negotiations that occurred as regulators worked on rewriting the permit for reissuance at the end of the five-year cycle. Because DEP attended meetings and actively solicited *and* incorporated feedback from regulated entities, the permit acted as a boundary object that helped participants span and engage the boundaries between local and state managers.

Following Senecah's [16] work, soliciting feedback alone did not build trust or demonstrate inclusiveness. It was the *influence* DEP allowed in certain aspects of the permit that promoted trust and mutual learning. When the regulator or state manager used the permit as a mechanism for enforcing inappropriate discharge, he or she reinforced the boundary. When the regulated entities engaged the permit to negotiate how they would meet requirements, offering their knowledge of local circumstances to improve the regulation, they spanned and reconfigured the boundary. Negotiation as a strategy created a context for learning across interpersonal and institutional boundaries. It was in these negotiations that local knowledge combined with scientific knowledge to influence regulation. The permit as boundary object reinforced the legitimacy of local and state officials' knowledge, concerns, and demands. Simultaneously, this boundary object helped create spaces that included all entities as part of the larger management group.

This case study demonstrates that the inclusive process promoted through particular communication structures (e.g., facilitation, agendas, opportunities for feedback, and airing concerns), improved participant access and standing [16]. The mutual influence through active listening, empathy for each other, and actual changes to local and state manager actions encouraged boundary crossing. This was possible in part because language used in conversations between collaborators in the BASWG gave each party and each form of knowledge the legitimacy necessary to be at the decision-making table [74]. This case study documents that regulations need not only define boundaries. Instead, they can serve as boundary objects that enable institutional and political boundary crossing, and, ultimately, strengthen the collective capacity for addressing sustainability issues like stormwater.

5. Systems and Difference: Internal Dynamics of Boundary Formation, Spanning, and Translation

Systems theories of communication comprise a diverse assemblage of theories and methods in which communication is generally understood as processes of material and symbolic interaction among different types of actors [91]. Constructs like boundaries emerge from these interactions. We draw broadly from systems theories and emphasize one in particular, namely Niklas Luhmann's [17] *Ecological Communication* (EC). Luhmann offers a useful illustration of social interactions that influence the construction and maintenance of boundaries. We elaborate two main points to explain social dynamics of boundary formation and discuss of each of these points in the context of boundary work. First, EC explains systems differentiation which helps account for how separation between institutional spheres like education, politics, law, economics, science, and religion occurs. EC describes how self-referential processes produce boundaries among different types of social arrangements. Second, Luhmann argues that systems differentiation occurs through binary codes, such as pass/fail, legal/illegal, true/false, *etc.* that operate within each subsystem. Codes structure relationships that then create boundaries in self-referential communication processes. This approach to understanding systems differentiation and the constitution of society through self-referential coding processes has been used to describe sustainability discourses and relationships among humans and earth systems [92,93]. EC as a lens can also help explain some of the challenges in boundary spanning and the use of boundary objects.

5.1. Key Features of Systems Perspectives: Parts to Whole Connections and Dynamic Cycles of Feedback

The worldview from a systems perspective rests on four foundational assumptions: wholeness, self-regulation, adaptation, and nestedness [94]. Monge [94] elaborates "The world viewed as systems consists of interlinked sets of components hierarchically organized into structural wholes which interact through time and space, are self-regulating, yet capable of structural change." Systems are comprised of parts that together foster an emergent property that is greater than each constituent part. Interaction between the parts and hierarchically nested levels produces meaning in communication. Luhmann [17] sees differentiated social spheres, such as institutions of law, education and economics, as parts that co-produce the larger whole of society. Relationships between the parts at multiple levels and the ways in which they constitute boundaries to produce nested wholes through communication are central to his analysis.

For Luhmann [17], social systems organize underlying complexity into spheres that have recognizable structures. These organized spheres then guide meaning derived through communication as interaction. The differentiation of spheres separates society from environment and creates boundaries among social institutions. According to Luhmann, science is a sub-system that uses symbolic representations to differentiate itself from the amorphous and infinitely complex environment and from other institutions, like politics. Luhmann argues that society organizes into at least six different spheres, including law, politics, economy, education, religion and science. Communication between operatively closed subsystems, such as when individuals who work within science attempt to communicate with those in politics, occurs through translation. Translation creates potential sites of new meaning. The primary purpose of communication becomes differentiation of

society from environment and society into its subsystems. Boundaries form through processes of differentiation and boundary objects may circulate to aid or hinder translation.

5.2. Binary Coding and Autopoiesis: Explaining System Differentiation and Boundary Formation

The organization of subsystems occurs through the selection for binary codes that structure the meaning, self-reference or autopoiesis, and communication. Binary codes are communication-related constructs that produce contingency, provide criteria for evolutionary selection, and allow for the co-existence of openness and closure within a system. Above all, binary codes' primary role is to differentiate the function systems. For example, accepting or rejecting the null hypothesis is not a binary coding scheme that applies to any of the other institutions, each of which has different sets of binaries that order meaning. The circulation of these different coding schemes internally feeds back within the subsystem and the boundary emerges around those individuals and institutions where the use of that coding system is operationalized.

Returning to the media analysis above, journalists' frames may also be interpreted as a kind of binary code, where journalists organize information into discrete frames. This is not a practice that scientists readily use to order meaning in their work, and translation between science and media thus becomes necessary. Training journalists in the practices of science and the ways in which meaning is ordered through hypothesis testing is one way to encourage boundary spanning. This perspective also highlights the self-reproductive, or autopoietic, effect of certain codes. As another example, framing vernal pools through science may help reproduce the boundary between science and policy in ways that effectively preserve the boundary around science, sometimes a key goal in boundary work. Situating media as one information channel within a system of binary codes and autopoietic processes contributes a more thorough analysis of the production and reproduction of boundaries of many kinds.

The self-referential processes associated with binary coding and the development of external boundaries from internal processes is also known as autopoiesis. Autopoiesis means to self-create and draws from second-order cybernetic tradition [95,96]. The ongoing production, reproduction, and maintenance of subsystems occur through autopoiesis in cybernetics, a mechanistic process within a network that guides system production and transformation [95]. Through the machinations of the parts, the network, "gives rise to components which, through their interactions and transformations, regenerate and in turn realize the network of processes that produced them" [95]. For boundary spanning, this means that some boundaries will be more permeable than others based on the self-referential processes that structure them and the translation requirements to span them. The internal dynamics that contribute to boundary formation may be an important contextual factor to consider in the selection of boundary spanning activities and boundary object use. These processes can also be used as a reflective lens to consider why in some cases attempts to span boundaries succeed and in some cases they fail, as we will now describe in the following case study.

5.3. Case Study: Systems of Difference in Disciplines Focused on Integrated Lake Research

This case study highlights interdisciplinary collaboration with sustainability science and SES lake research teams. Our discussion draws from three years of participant observations in the Sustainability Solutions Initiative (SSI), 41 interviews with faculty and graduate students, and on online survey that

asked about working across different types of boundaries. Luhmann's [17] systems theory helps elucidate some of the potential complexity associated with boundary spanning and the use of boundary objects in different forms of collaboration. We take up Luhmann's theory as a lens to explain some of the potential internal processes occurring within the research team context. Understanding binary codes and the self-referential processes that create subsystem boundaries among individuals and institutions may influence the selection of strategies and objects in boundary spanning and critical reflection on why processes of translation sometimes work and other times fail.

Researchers on SSI teams study lakes as dynamically integrated human and natural systems. On one team, faculty members hail from a single institution, though they are at different stages in their respective careers and are housed in multiple departments across the natural and social sciences. They are concerned with the sustainability of a lake ecosystem that provides drinking water, recreational benefits, and aesthetic value to citizens. This coupled lake system also has rapid urban development within the watershed and is marked by conflict over specific management issues. Despite their similar interests and geographic proximity, this team acknowledges the multiple challenges they have faced as they seek to find ways to work through difference. One of the members characterized much of their work as representing a failure to cross interdisciplinary and transdisciplinary boundaries.

The following quotation from an interview from our research on interdisciplinary collaboration resonates with the case example on lake dynamics and illustrates language structure and translation:

> I've worked with a lot of natural scientists. I think working with other social scientists has sort of actually been more difficult, especially ones who use more economics or modeling kind of things. I just do focus groups and interviews and the people who use economic quantitative models don't really get it. Probably it's mutual. So I'm trying to find a better way to work with economists.

Of this challenge, Luhmann might argue that while these researchers are situated within a shared subsystem within an institution of higher education, they are also simultaneously differentiated at the level of disciplinary systems and may be working within separate coding structures. The experimental researcher who uses the binary of accepting or rejecting the null hypothesis operates within a sub-system that may differentiate her from a researcher who does not use experimental design even though they may share other characteristics. The autopoietic self-referential processes within these systems will maintain the boundary between the two, and arguably, impede boundary spanning.

Luhmann's EC is useful to understand pragmatic approaches to boundary spanning in sustainability science because, at a basic level, this theory calls attention to the internal processes of boundary formation and some of the complex communication dynamics that may impede translation across the boundary. On one level, the use of boundary objects may fill an important role in linking arenas. In the case of the use of modeling one might argue that models facilitate communication because they provide a common frame of reference and assist in the process of information exchange as an ideal type or a standardized form [28]. However, as Jasanoff [30] points out, contestation around boundaries "are played out in the realm of language. The discourse of risk regulation has provided fertile ground for the creation of new linguistic labels whose primary function is to delimit the boundary between science and political processes." The linguistic labels she describes may be understood through Luhmann's [17] binary codes, in which the linguistic label "trans-science" becomes a structuring

binary that serves to differentiate and reify the separation of the two spheres by possibly creating a new, third sphere in between but that does not actually serve an intermediary role [30]. Models may function at the level of a linguistic label where instead of facilitating communication they are actually creating a new subsystem unto themselves. The multiple possibilities in processes of translation and system construction invite consideration to explain why, in some cases, there is a failure of boundary spanning processes. In the lake research example, the model contributes to the production of social order on the team and may delimit a space of participation that is not inclusive of other ways of knowing the world. In this context, where the goal is to make the boundary between disciplines more permeable, language impedes successful boundary crossing and creates a point of focus for identifying strategies to negotiate new meanings [72].

6. Discussion and Conclusion

In our expansive trek through communication theory and method, we crossed boundaries among media studies, collaboration and partnerships, and systems theories of communication. Each of these adopts context dependent orientations to communication and boundary. From media studies, we learn that communication as a system of representation constructs how message circulate, the possible social effects in society, and how training around the development and use of boundary objects may influence spanning and management in strategic ways. Collaboration and partnership literature contributes a focus on interpersonal dynamics and emphasizes issues related to inclusiveness, equity, and legitimacy in how language creates spaces of action. Boundary work relies on the use of boundary objects to create shared participatory spaces and a commitment to working through but not erasing difference. Finally, systems theories explicate cyclical and internal feedback processes that produce and maintain boundaries within institutions like science, policy, and media. Understanding how the circulation of particular patterns of language, such as the use of binary codes, influences the (re)production of boundaries helps to identify some of the complexity with spanning and management. Each of these orientations to communication serves as a flexible lens to describe and produce context and identify strategies for successful boundary work.

Here we return to the theme of transdisciplinarity to organize the primary implications of our work (Table 1). Transdisciplinarity offers at least three heuristics for elaborating these implications: (1) the focus on *ideal* process phases in which capacity grows and transformations occur at multiple sites of experience; (2) a commitment to critical self-reflexivity in knowledge co-production; and (3) attention to difference, tensions, and power relations in boundary work. The questions we pose in Table 1 and on which we expand in the latter points below are potentially relevant in every phase, depending on the context and the actors and institutions involved. We do not situate the questions in one phase or another but instead offer them as a reflective tool to understand communication as phenomena arranged in a multitude of ways [14]. Following these transdisciplinary heuristics, we highlight three primary implications from our analysis. In the first we argue the need to grow capacity within academic institutions for boundary work and in the two that follow, we orient this capacity along reflective and generative trajectories.

6.1. Grow Capacity within Academic Institutions for Boundary Work

One of the primary implications of this paper is the need for academic and other research-oriented institutions to coordinate, aggregate, and re-direct resources to engage complex problems through transdisciplinary sustainability science approaches, with an attendant commitment to boundary work [97,98]. Cultivating the capacity to approach complex problems from multiple standpoints and collectively identify process considerations for each unique context is a key contribution institutions of higher education can make to sustainability science [21]. Within their stated missions to promote inquiry and learning for societal enhancements, academic institutions are uniquely positioned to foster reflective practice in boundary work that could potentially lead to innovative insights that would otherwise not be available. A commitment to transdisciplinarity prioritizes understanding societal needs for science and encourages universities to position themselves as agents of and partners in social change. This, in turn, requires organizational innovation [99] that reconfigures the resources, institutional structures, and activities that higher education provides [100].

Such reorganization ranges from rethinking how graduate students are trained to how faculty and research units are rewarded to how the university-society boundary itself is managed and spanned. Engagement with specific communities means reconceptualizing universities' mission as a form of adaptive leadership that encourages social learning and change in the context of local and global networks [101]. Building transdisciplinary capacity thus requires coordinated efforts to mentor and train, promote networking, provide technical support, and produce cutting-edge curriculum to enable participation and self-efficacy [98]. As our case studies clearly demonstrate, communication research can help to inform these efforts.

However, as we learn from the discussion of the multiple dimensions of boundary work in the constitution of objects and social order, capacity building must also extend beyond prescriptive solutions such as training programs and curriculum development [6]. These efforts will need to address fundamental cultural changes within academia [98] and the paradoxes that accompany these kinds of transformations [21]. As Russell *et al.* [21] point out, paradoxes occur within efforts to promote interconnection/consolidation and knowledge co-production/mutual learning. The development of intellectual capacity must engage these and other paradoxes and use them productively to promote reflective transformations within and outside academia [21,97,102].

Two features then are central to working with paradox to promote capacity for transdisciplinarity: cycles of reflective inquiry and a commitment to difference as an engine for creativity. Within each of these, we offer questions drawn from our discussion of communication and boundary work to help guide the development of this intellectual capacity (Table 1). These questions contribute to those articulated by Lang *et al.* [11] for the continued development of transdisciplinary frameworks that also pay close attention to multiple dimensions of communication.

Table 1. Summary of communication orientation, the boundary dimensions that orientation helps explicate, and core questions within a transdisciplinary process framework to describe context and identify strategies for enhanced boundary work.

Communication Tradition	Orientation to Communication	Boundary dimensions	Transdisciplinary Process: Questions for Context and Strategies
Media studies, Framing	Mass communication is largely based in representations using words and symbols to construct meaning.	Frames may serve as boundary objects. Strategic coordination of frames may help in boundary spanning and management. Training should focus on scientists and journalists as boundary spanners and include time for face-to-face interaction.	Who are the likely boundary spanners? What resources are available to promote training around the use of media frames as boundary objects? What is the impact of strategic frame use on the co-production of knowledge and social order?
Collaboration & Partnerships	Communication is socially-constructed in interpersonal relationships.	Boundary work aims towards inclusivity and equity for enhanced spanning. Boundary objects participate in defining legitimacy of social constructs. Boundary objects, like worksheets, can help the pragmatic coordination of activities.	Who has voice? Who needs voice? How does communication influence access, standing, and influence? How we can change the context in ways that make the inevitable struggle for power more equitable? How, through language, can we co-create legitimacy in ways that align with core commitments in sustainability?
Systems theory, Ecological Communication	Communication occurs through binary codes to produce system differentiation in self-referential processes.	Boundary work occurs through a process of translation across sub-systems. Boundary spanning may be impeded by coding structures within institutional domains. Boundary objects may facilitate crossing and may also create new subsystems.	What are the language structures that order meaning for collaborators operating in different sub-systems? How does the use of boundary objects operate in translation across boundaries? What other strategies, objects, and training opportunities may be employed when translation processes fail?

6.2. Create a Sustained Commitment to Cycles of Reflective Inquiry

A commitment to sustained reflective and critical inquiry within collaborations enables the identification of core process questions. These questions help us understand boundaries and identify strategies to cross and manage them. Instead of one-size-fits-all tactics, media studies, collaboration and partnerships, and systems theories provoke adaptable question sets. For example, in the vernal pool case in which the boundaries among scientists, journalists, and legislators became a matter of concern, key questions to better understand the context and co-develop strategies for enhanced boundary work ask: Who are the likely boundary spanners? What resources are available to promote training around the use of media frames as boundary objects? In the case of the lake systems research, the failure to cross boundaries invites the question: How does language participate in the creation of meaning in one discipline as compared with another? When we use boundary objects, are they enabling translation across subsystems or are they producing a new domain entirely? If the latter, do boundary objects contribute to satisfaction in the collaboration and progress toward stated goals or not?

Some sustainability science programs at universities have incorporated self-reflexive research focused on understanding how the organization functions and feeding that information back to improve efficacy, strengthen collaboration, and ensure equity. Our SSI project, for example, includes organizational innovation research that studies a range of issues central to our mission. This research has focused on understanding what factors influence inter- and transdisciplinary collaboration and how we might enhance organizational structures to incentivize approaches that lead to productive outcomes. It has also sought to understand how language itself creates challenges within our teams and ways that, through language, we can make process improvements. We encourage sustainability science to focus on team dynamics from the outset, to ensure that all collaborators understand the importance of self-reflection and the need to include feedback from various perspectives in decision making and governance structures.

6.3. Approach Difference as an Opportunity for Novel Insights and Mutual Learning

A core commitment in Daniels and Walker's [73] CL approach is to find ways to work through difference but also maintain difference because it can be productive for new insights and creativity. Jahn *et al.* [10] agree with this assertion, pointing out that integrating disciplines is not about blending approaches to knowledge production, as if we could take the best of methods in one discipline and match them with the best of methods in another. Instead, integration focuses on the reflective inquiry in knowledge production processes to create the space for the social production of meaning, learning from difference, and mutually-derived action plans. Following this orientation, in each of our case studies we avoid the language of "overcoming" and "getting past" difference and instead find productive points of tension to ask questions to spur the emergence of context-dependent and situation-transcendent strategies. Approaching difference as a driver for creativity points towards another crucial consideration which each of our communication theories implicitly addressed but did not discuss in full, namely power. Power can be understood in many ways, though we adopt a common conception within communication which understands that power is relational and creates the conditions for what we come to see as possible [103]. Our discussion of collaborations and partnerships brings issues of

power to light in the most direct way; others have also noted the crucial importance of power within inter- and transdisciplinary collaborations [104,105]. Attention to power in relationships requires us to ask: How do our language practices and the spaces of interaction influence who expresses voice? Whose voices remain silent? How we can change the context in ways that make our common struggle for power more equitable?

Returning to Clark *et al.*'s [1] discussion of boundary work within sustainability they emphasize attention to power as "essential to good boundary work. Implementing this realization would constitute a major departure from the apolitical, one-directional "transfer" models that still inform much of the dialogue and practice of science for development." Strategies to enable the inclusion of voice and creativity from difference will likely vary but paying attention to power as it circulates through communication practices is a key context consideration that can be guided by these and other process-based questions. Attention to power also becomes paramount when we consider that a solutions-driven approach will require decision making to occur and inevitable compromise within these complex situations. If collaborators are not sensitive to power and do not include diverse voices in the production of compromise, equitable compromise is less likely to occur.

Transdisciplinary approaches to sustainability science ask us to recognize, understand, and act on the complex interconnections among all of the planet's systems. We see this as an invitation to meet complexity not with simplicity but with flexibility, multiplicity, sensitivity to context, and ultimately, strategy. The communication theories and methods we describe do not try to resolve the complexity and dynamism inherent in sustainability science. Instead, they provide a set of lenses to understand some of the complexity and identify tools and strategies for engaging in boundary work to help make decisions in the face of it. Question sets, as opposed to best practice lists, maintain a commitment to Clark *et al.*'s [1] sense that strategies should follow context. These questions also provide a way to transfer insights from one context to another without being locked into prescriptive approaches. Questions themselves become boundary objects and will be valuable as institutions and individuals engage in capacity building for sustainability science, commit to cycles of reflective inquiry, and attend to power and difference within these efforts. Communication as a field helps foster the conditions for the kind of flexible, reflective, and equitable standpoints that we will need as we collectively draw boundaries around our shared futures.

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Conflicts of Interest

The authors declare no conflict of interest.

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