

Tacking amid tensions: Using oscillation to enable creativity in diverse teams

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Abstract

Diverse teams may potentiate greater creativity through divergent thinking. Yet research suggests these teams face a dilemma: the very features that make them promising are associated with persistent communication challenges that threaten their effectiveness. We turn to the literature on dialectical tensions to argue that a process of oscillation, consisting of repeated alternation between moments of divergence, emphasizing the differentiation of perspectives, and moments of convergence, emphasizing integrating ideas to produce coordination, may mobilize the tension between differentiation and integration effectively. We explore the utility of our framework by applying it to the experiences of a diverse cohort of researchers who engaged in a purposefully designed oscillatory process to generate research projects related to climate resilience. Our multi-method evaluation of this case indicates that oscillation was effective for creative idea generation. This work contributes to both practice and scholarship in interdisciplinary teamwork support, creativity, and organizations.

Keywords: Collaboration, Teams, Diversity, Creativity, Divergence, Convergence, Group Processes

Tacking amid Tensions: Using Oscillation to Enable Creativity in Diverse Teams

Sailing ships cannot move directly into the wind, but they often need to go in that direction. How does one sail against the wind? A crew does this by tacking—that is, turning the craft so that the direction of the wind changes from one side of the sail to the other. Tacking is about balance. Stay too long on one course, and you will miss your target; stay too long on the other, and you will lose headlong momentum. The result is a weaving course that makes steady progress against a prevailing wind. This oscillation helps the crew advance toward their objective.

Tacking requires tight coordination among crewmembers and crews are, of course, teams. In this paper, we argue that navigating the challenges of diverse teamwork requires strategies not unlike a sailboat's tacking. Such a strategy enables a diverse team to move against social forces that would otherwise steadily push against team creativity: the very characteristics of diverse teams that make them promising for creativity also make them fraught with obstacles. Diverse teams can assemble a wider array of knowledge than any single individual (March & Simon, 1958). Yet diversity also produces persistent communication challenges. Differing backgrounds introduce differences in perspective, values, and motivations that can hinder members' ability to work together (Keyton, Ford, & Smith, 2008) and these teams may experience disproportionately heightened conflict and coordination costs (Cummings & Kiesler, 2007). Unfortunately, current research can suggest “relatively little about how organizations *should* [emphasis added] be managing diversity effectively” with confidence (Guillaume et al., 2014, p. 798).

This paper seeks to build theory on how diverse teams can facilitate creativity by actively managing the tension between differentiation and integration. We identify a theoretical mechanism similar to tacking as a potential tactic to address this tension. We begin by first

exploring tensions in diverse teams. We then use this grounding to argue that repeated alternation—what we call oscillation—should help teams take advantage of the benefits of each end of the differentiation-integration tension while affording flexibility to pivot when the teams start to experience the negative impacts of one side. We explore these claims by analyzing the experiences of a diverse cohort of researchers focused on addressing resilience to climate change whose engagement was strategically designed with a grounding in oscillation. Our analysis provides initial evidence that the procedure created alternating periods of integration and differentiation as theorized, and that this oscillation positively contributed to team outcomes. To close, we discuss how these findings help generate theory about the experiences of alternation, and how these contributions can motivate the design of a potentially replicable procedure.

Using Oscillation to Foster Creativity in Diverse Teams

Creativity has historically proved a challenging concept to operationalize (Amabile 1996). Most conceptualizations describe creativity as a quality of an object or product. An advantage of this conceptualization is that it allows researchers to evaluate, measure, and analyze well-defined, discrete products through variance methods. However, others have also conceived of creativity as a process. When viewed as a process, creativity is inherently embedded in its context and temporal in nature (Poole, 2013). One benefit of this view is that it emphasizes the role that communicative and organizational factors play in the production of creativity. To study creativity requires understanding the complex, dynamic processes that underlie idea generation, as it is “difficult to study the activities or steps in which change and innovation unfold using variance methods” (Poole, 2012, p. 379). We conceptualize creativity as the process by which a team produces solutions, products, or processes that are new, impactful, and useful (Amabile, 1996; van Knippenberg & Hoeve, 2017). Creativity may occur through a sudden insight or

invention, but more often happens when individuals and teams explore and combine previously unconnected ideas (Hargadon, 2003). When effective, this process produces outputs that are novel compared to the existing state of the art (Amabile, Barsade, Mueller, & Staw, 2005).

Diversity can be a key enabler of the creative process. Diversity, operationalized here as the presence of multiple differing perspectives toward a research problem, has long been regarded as a potential wellspring for creativity and innovation. Indeed, Van Knippenberg and Hoyer (2017) write that diversity may be the “sole, most important reason why teams may be better suited to perform creative tasks than individuals in isolation” (p. 43). It is important to mark that our operationalization centers the role of informational diversity (the presence of differing knowledge among team members) over other important aspects of difference that influence team dynamics (e.g. trait or value diversity; van Knippenberg & Mell, 2016). While all aspects of diversity are important, we center informational diversity here because past research has tied this type of difference most closely with the potential for team creativity (Jehn, Northcraft, & Neale 1999; van Dijk, van Engen, & van Knippenberg, 2012). Diverse teams corral a multitude of experiences and skills that afford a wider pool of knowledge to foster the creative process than that which is available to individuals or uniform teams (Brandon & Hollingshead, 2004). As a result, diverse teams are positioned to diagnose and understand complex problems, such as the creation of knowledge products like patents (Chunlei, Rodan, Fruin, & Xiaoyan, 2014) or addressing pressing challenges in science (Uzzi et al., 2013).

Diversity also engenders communication challenges. Differing languages, values, and motivations can hinder collaboration (Carlile, 2004; Keyton, et al., 2008), and diversity can be a source of conflict (Jehn, Northcraft, & Neale, 1999; Larkey, 1996). When not managed effectively, conflict can lead to destructive behaviors such as arguments, withdrawal, and

avoidance (Weingart et al., 2015), reduced trust (van Dijk, Meyer, van Engen, & Loyd, 2017), and decreased team cohesion (Guillaume et al., 2014). Engaging in diverse teams can also involve higher potential for failure largely because of these communication challenges (Cummings, Kiesler, Zadeh, & Balakrishnan, 2013; Leahey, Beckman, & Stanko, 2016).

These mixed findings suggest that *how* a team addresses diversity can affect its creativity. As we see, simply increasing diversity is not adequate alone to increase creativity while maintaining effectiveness. Diversity scholarship has explored multiple mechanisms to address this issue. One approach is to emphasize the importance of integration processes on diverse teams, which should reduce some negative impacts of high member heterogeneity. Guillaume, Brodbeck, and Riketta (2012) developed propositions that frame integration as a way to build members' sense of belonging on diverse teams. The authors argue that members of diverse teams are less likely to identify with members of their team and thus less motivated to contribute, decreasing the team's overall effectiveness. One suggestion, then, is that managing team diversity requires a focus on social integration to create a unified team identity that motivates diverse members to come together to achieve a common goal. Although Guillaume et al. (2012) provides an example of how integration can help teams manage diversity for effective outcomes, practitioners are still left without clear guidance on how to simultaneously harness the benefits of having differences. Integrative solutions minimize, rather than capitalize on, diversity. Thus, we believe it is crucial to consider strategies that allow teams to integrate and find common ground while *also* helping teams draw on diverse perspectives that catalyze the creative process. We believe this managerial challenge—balancing the costs of diversity with its benefits—is due to a fundamental tension: the dual needs of integration and differentiation.

The Differentiation-Integration Tension in Diversity

Communication research has long acknowledged tensions as an inherent characteristic of organizations (Erhardt & Gibbs, 2014; Poole, 2013; Poole & Van de Ven, 1989; Putnam, 1986; Putnam, Fairhurst, & Banghart, 2016). Collaborative work engenders multiple tensions that members must address if they are to succeed (Poole, 2013). We argue that the promises and challenges of creativity in diverse teams are enacted through an ongoing tension between the opposing states of differentiation and integration. A sensitivity to dialectical tensions leads us to recognize that this opposition is not something that can necessarily be eliminated or reduced; rather, we must accept this tension within diversity as a persistent pressure and ask how to manage it (Ferdman, 2017). In the section below, we conceptualize this tension as an avenue to design procedures to employ it in creative processes.

Teams face an enduring challenge of meeting the need for specialization on one hand and coordination on the other (March, 1991; Lawrence & Lorsch, 1967). *Differentiation* takes advantage of differences within a diverse team, including differences in background, experience, discipline, and values (Folger, Poole, & Stutman, 2018). This state potentiates creativity because it allows the group to capitalize on its diversity of perspectives in a domain (March, 1991). But if differentiation becomes too pronounced and unchecked, it can fragment the team and produce conflict. Differentiation can be a wellspring of ideas but may also foster conflict by foregrounding differences.

Integration compensates for these negative tendencies by generating cohesion and allowing ideas to come together towards common ground, keeping the team together, and allowing for work coordination (Grant, 1996; Nonaka, 1996). But integration can homogenize the team and dilute the benefits of differentiation based on diversity. Integration enables coordination, but also increases the likelihood of biases due to conformity pressures and, in some

cases, may reduce the range of ideas available to the team. These contradictory needs are a defining characteristic of creative diverse teamwork. As a result, differentiation creates greater need for integration, but swinging back to the integration state simultaneously creates a greater need for differentiation. If the team emphasizes only one state, it will lose the benefits of the other; in essence, each pole is antagonistic (Lawrence & Lorsch, 1967). As Cropley (2006) writes: “[b]oth too little and too much is bad for creativity” (p. 2). Both sides are necessary, but also limiting. This tension is particularly salient with diverse teams: Their primary advantage (a plurality of perspectives and expertise) is also their primary challenge (a need for coherence and coordination), making diversity eternally Janus-faced. Diversity thus provides a conundrum, which requires not just understanding, but managing, its core tension. Fortunately, this dialectic can be addressed by the dual procedures of divergence and convergence.

Leveraging the Differentiation-Integration Tension through Oscillation

One avenue for addressing this tension evolves from our recognition of the processual nature of creativity. Innovative ideas develop iteratively, and this process is not uniform over time: moving between the two states of differentiation and integration requires strategies that intentionally focus on harnessing the benefits of each state. Organizations that are simultaneously able to highlight both differentiation and integration to a high degree may be the most successful (Puranam, Singh, & Chaudhuri, 2009; Teriesen, Patel, & Sanders, 2012). How can teams utilize this tension for creativity?

Cropley (2006) describes divergence and convergence as contrasting creative phases. *Divergence* is a period of work that emphasizes multiplicity and difference through which groups rapidly develop ideas. In this way, divergence directly addresses the need for differentiation. Divergence produces a rich variety of ideas and knowledge for team members to use in their

work and provides opportunity for discovery and recombination of ideas in novel ways (Cromptley, 2006; Georgiev & Georgiev, 2018). But this constellation of resources can lead to ambiguity about how the team should proceed. In contrast, *convergence* is a period of work that emphasizes unity and shared focus (Cromptley, 2006). Here, the team reduces or combines ideas to achieve joint direction toward common solutions (Brophy, 2001). As a team converges, it moves toward integration, which permits the formation of connections based on potential solutions' trade-offs, syntheses, and emerging higher order concepts (Suedfeld, Tetlock, & Streufert, 1992). As with divergence, strict convergence can be problematic: this phase has the potential to arouse uncertainty, as team members may question whether they will be validated and included or invalidated and excluded. This, as well, can lead to conflict as teams struggle to situate themselves for future progress. Thus, both processes are necessary to leveraging diversity and creativity in teams, and neither is sufficient alone.

The divergence-convergence model has traditionally been viewed as a two-stage process—first divergence, then convergence (Cromptley, 2006). But, a two-stage process does not fit the dynamic, processual nature of idea generation and creativity. Team creativity is iterative and recursive; ideas are generated, combined, and amended as part of an ongoing process. A non-linear understanding of creativity reflects research stating that novel insights do not just occur *all at once* but may emerge from iterative drafts and from dwelling with a problem over an extended period (Goh, Goodman, & Weingart, 2013; van der Vegt & Bunderson, 2005). Current studies on divergence and convergence recognize the necessity and utility of both in creativity processes. “Recent accounts of creativity...highlight the interwoven role of both convergent and divergent thinking...both convergent and divergent skills [are needed] in equal proportion”

(Georgiev & Georgiev, 2018, p. 2). Divergence and convergence are stronger when combined and should be seen as “complementary processes” (Brophy, 2001, p. 452).

Our conceptual framework to address this tension relies on two primary ideas. First, that creativity is a dynamic and interactive process that occurs over time, and second that divergence and convergence work best when building off the other. The emergent idea, then, is to create a specific process that allows both convergence and divergence to occur repeatedly in the same space and over time. Drawing on this idea, we propose an oscillating pattern of divergence and convergence. Given the shortcomings of a phased approach, the challenge should be to manage the core differentiation-integration tension over time. Fortunately, the literature on organizational tensions offers a potential solution.

One way to address this tension is through a strategy of alternation. Alternation embraces dialectical contradictions through processes that emphasize each pole (Baxter & Montgomery, 1996; Poole & Van de Ven, 1989). Therefore, instead of a single two-stage process, a strategy of repeated alternation would suggest diverse teams should be subject to continuous oscillation, much like a sailboat continually tacking against the wind. By oscillating, teams should prevent momentum toward either side of the differentiation-integration tension, which should accommodate the complex, longitudinal nature of creativity. A dynamic of oscillation can destabilize the divisive impact of diversity during convergence. Temporal and life cycle variables, such as group member tenure, team longevity, and time, might positively moderate workplace diversity effects because it likely takes time to overcome stereotype-based impressions and uncover unique information, knowledge, and perspectives associated with workplace diversity (van Knippenberg & Schippers, 2007).

Oscillating between divergence and convergence periods enables diversity to re-express itself in ways that make future convergence periods more productive and less likely to lead to impasse. This would generate a tightening spiral that can lead to increasing integration and unification of the team around a creative concept. The two states can capitalize on their tensions and build on the benefits of both integration and differentiation while mitigating negative effects of either. Through repeated alternation teams can repeatedly “tack” between divergent and convergent activities over time without remaining for too long at any one side. Figure 1 provides a conceptual illustration of this proposition.

[Insert Figure 1 about here]

Accordingly, we designed a procedure to promote oscillation as a mechanism to foster a creativity-inducing environment. Therefore, we ask:

RQ1: How do the participants describe their experiences as they move through the oscillating process?

Addressing this question enables us to ascertain what the procedure “does” to the participants, and whether they view the oscillation as fostering positive experiences that promote group productivity. This leads to a second question which builds on the first:

RQ2: Does the proposed strategy facilitate team creativity and the production of creative products?

Methods

We engaged in an applied intervention as a method to initially assess our approach and develop our understandings of how individuals on real-world teams experience oscillatory processes. Driven by our framework, we designed an intervention with the goals of: (a) supporting the ongoing interaction of groups of diverse individuals over time; (b) incorporating

recurring oscillations between periods of convergence and divergence, as opposed to a single cycle; (c) enabling members to progressively build on one another's ideas so that a common set of projects emerges; and (d) promoting assessment of ideas based on the multiple perspectives of group members, thus ensuring that it takes advantage of diversity.

To permit longitudinal engagement required by our framework, we designed our procedure to engage a cohort of researchers in a series of activities occurring over a period of six months. The core structured activities involved a series of three workshops (2-3 days each) over this period, each designed to lead the cohort through repeated cycles of divergence and convergence. The content of the workshops guided the cohort through defining projects, forming teams (workshop 1), and working towards a project through ongoing iteration and feedback (workshops 2 and 3). Drawing on the notion of alternation as one way to manage diversity's central tension, each workshop was structured to facilitate oscillations between states of differentiation and integration that would repeat over the entire course of the process.

We drew on divergent procedures, such as brainstorming techniques, to encourage differentiation in a way that emphasized the cohort's differing knowledge. We drew on convergent procedures, such as facilitated discussion and thematic analyses, to encourage teams to consolidate their wide perspectives into an integrated state. Appendix B provides a detailed workshop agenda for the first workshop and a conceptual justification underlying our choice of activities and how we sought to produce longitudinal oscillation. The result was a longitudinal procedure that shifted between divergent and convergent phases. The guiding intention was that teams would experience repeating periods of work that alternately highlighted and satisfied the contrasting needs of integration and differentiation, multiple times each day and at times multiple times within an hour. For the sake of parsimony, Appendix B only describes the procedure of our

first workshop to illustrate this principle in action. Detailed agendas for the second and third workshops are available from the authors upon request.

Beyond the periods of oscillation designed into the workshop agendas, we structured the intervening periods between the workshops to facilitate further iterations of the oscillation. The groups worked apart during a three-month gestation period where the research teams developed their ideas into proposal drafts. The groups reconvened at a second workshop for a day and a half to further develop their projects, which focused on clarification of projects and engaged discussion on maximizing each project's potential. Following this workshop, the groups continued to develop their projects with guidance from organizers and expert grants writers. Figure 2 provides a summative illustration of the procedural process and the long-term oscillation occurring across the course of several months.

[Insert Figure 2 about here]

Application to Scientific Teams Addressing Climate Change

We chose the scientific problem of resilience to climate change as an initial context to apply our framework for several reasons. First, climate change is one of the most pressing issues requiring scientific and creative problem solving (Committee on Key Challenge Areas for Convergence and Health, 2014). Second, reports have characterized climate change as a “wicked problem” requiring coordinated attention from diverse communities (Committee on Facilitating Interdisciplinary Research, & Committee on Science Engineering and Public Policy, 2005). Last, the term “climate resilience” was sufficiently ambiguous that we could harness its polysemy to recruit a diverse population of participants.

We recruited 17 participants from a pool of applicants based on their research records and potential for producing impactful research. Participants represented 13 academic institutions (six

Historically Black Colleges and Universities, three Hispanic Serving Institutions, three Tribal Colleges and Universities, and one Land Grant University) and nine distinct disciplinary identities (Atmospheric Science, Biology, Chemistry, Environmental Science, Geography, History, Indigenous Studies, Physics, and Urban Planning). Participants represented a variety of career stages: five assistant professors, one associate professor, one associate researcher, two industry professionals, two full professors, two PhD students, one adjunct professor, two instructors, and one teaching assistant professor. 12 participants were male and five were female. We did not collect explicit data about participant ethnicity to avoid potential perceptions of tokenization during the process of selection and procedure (Turner, Gonzalez, & Wood, 2010). Additionally, because we sampled, in part, from small, region-specific institutions in specific fields, reporting more detailed demographics of participants may have posed a real risk of exposing the identities of some participants. We reasoned that sampling researchers from such a range of institutional and disciplinary backgrounds would provide sufficient informational diversity to address the project goals.

Assessment Methods

We collected a broad range of data to assess whether our procedure produced the intended oscillation process, and how participants experienced the procedure in action. Drawing from tenets of grounded theory (Corbin & Strauss, 2014; Gioia, Corley, & Hamilton, 2012), we approached our data collection and analyses with a sensitivity to the fact that the researchers were situated in the production of the findings and measurements. We collected data from four primary sources: (a) workshop questionnaires, (b) semi-structured interviews with participants, (c) external assessments of project proposals, and (d) other associated procedure outcomes (such as measures of team characteristics, secured funding, number of ideas generated, finished

proposals, etc.). We drew on these multiple data sources to allow us to triangulate our results (Eisenhardt, 1989), as triangulating better allows researchers to bolster the validity and reliability of results (Tracy, 2013).

We administered surveys at regular intervals between workshop sessions to allow us to capture participant responses to the process *in situ*. In these questionnaires, participants were encouraged to reflect about that moment in the workshop. Questionnaires included two items where participants indicated their current energy and satisfaction and one open-ended item where participants recorded their thoughts at that moment. Because participants responded to these questionnaires in interstitial periods between activities, the resulting data captured feedback in real-time. In the subsequent analysis, this would permit us to tie responses to specific moments in the process. Next, at the conclusion of the final day of each of the workshops (workshops 1, 2, and 3), participants responded to a post-workshop questionnaire that captured summative assessments of the process and invited reflection on each of the major sessions. As opposed to the real-time questionnaires, the post-workshop questionnaire permitted participants to reflect holistically on each session in the context of the larger process, as well as to provide perceptions of important team outcomes like cohesiveness and efficacy.

The next source of data came from NSF-style project summaries each team produced at the conclusion of the procedure. These summaries were evaluated to provide an initial indicator of whether external audiences perceived the teams' products as creative. The results from this analysis would serve as part of the assessment of the relative effectiveness of the process, as the ultimate goal of the process for participants was for their teams to develop and submit novel project proposals. We analyzed these documents using Amabile's (1996) creativity evaluation technique, which involved recruiting a group of subject matter experts to evaluate the projects on

three dimensions of creativity (see Appendix A for full measure). A detailed description of this procedure follows in the findings section.

Finally, we conducted semi-structured interviews to solicit participants' elaborations about their experiences working within an environment grounded in oscillation. The research team conducted these interviews by phone and each interview took between thirty and sixty minutes. In total, 13 interviews were conducted; four members of the cohort were unable to be interviewed. Given the researchers' embedded position in the design and evaluation process, we took two steps to encourage candid responses from our participants. First, the members of the research team who performed the interviews were not actively involved in designing and facilitating the procedure. Second, we made participants aware their interview data was embargoed from the workshop facilitating team members until after the procedure was complete. This had the added advantage that interviews would not create biases that potentially reduce negative responses by participants.

The first author began analysis by open coding interview recordings and open-ended survey responses. To ground ourselves in the data, we purposefully approached this round of coding without a sensitivity to any specific theory. The first author assigned descriptive codes which summarized the primary topics discussed by the participants in each segment of the interviews. The analyst did not attempt to collapse codes to allow emergent categories that would follow the manifest topics. This round of coding revealed recurrent accounts of participant experiences and perceptions of process, which began to suggest that process and oscillation were a good fit for these data.

In the next phase of analysis, the first author conducted a round of selective coding. In this stage, coding was sensitized by an interest in the broad questions of process and early

notions of the oscillation framework we had been developing. The selective coding process led to isolating any instances where a participant discussed their teamwork processes or experiences during and between the workshops. Next, through an emic process, each of these instances was marked in accordance with two broad patterns. An instance counted as involving teamwork processes any time a participant described how their team or a team member had worked (during, after, or between the workshops) or how they perceived the team was functioning (including evaluative statements). An instance counted as an experience of the workshop any time a participant described an evaluation of the process (negative, positive, or ambivalent), their feelings or thoughts during the process, or feedback on the process or procedures (including recommendations and critiques). An “instance” in the data began at the first point in the conversation when any of these examples was observed and ended when the topic of conversation changed.

The previous round of coding resulted in coded sections of data that specifically involved the process and experiences of the process. The first author proceeded with a second round of selective coding, using an interest in how participants experienced and perceived the process as a sensitizing lens. For example, codes were applied for the valence of the comment (i.e., positive, negative, or ambivalent), for the distinction between discussion about the procedures versus teamwork (although these categories were not mutually exclusive), and contextual information, among others. These codes were developed emically and applied iteratively; codes were not determined a priori. Rather than allowing theoretical frames to drive the analysis, codes were directly drawn from participant experiences in the data and elaborated on throughout data analysis.

Now that there was a general understanding of the kinds of statements made and the contexts in which they were made, we were prepared to begin searching for linkages between these instances of experiences and perception. This began the second stage of analysis, which included the other researchers. As a group, the researchers participated in a round of axial coding, whereby we aggregated themes into categories (Corbin & Strauss, 2014). Resulting from this round of axial coding, several categories emerged. Specifically, categories included accounts of how the process affected work and outcomes, experiences during the workshop in relation to the switches between different types of tasks, and a growing/changing perception of the nature of work on such a team. As a final round of analysis, the first author revisited the data to make sure no further categories emerged. When none did, the analysis concluded. Each of the categories related directly to elucidating the experience of oscillation on team and outcomes, and constitute the findings discussed below. Importantly, a cross-cutting theme across these was recurring findings that participants did experience and perceive periods of oscillation during the process.

Findings

Participant Perceptions of the Procedure

We expected that the procedure would produce periods of integration and differentiation and, ultimately, have positive effects on the creativity process in the diverse teams. The following section explores these expectations by considering participants' reflections on their experiences. Analysis found three broad themes in the data: (1) perceptions of the procedure's role in outcomes and processes, (2) perceived uncertainty, and (3) perceptions that work required "balancing" of tensions.

Attributions of success as resulting from the procedure. Participants credited the procedure itself as a key driver of the outcomes they experienced, identifying three components

of the design as playing important roles in their creative process. First, participants acknowledged the presence of diversity as a key basis for their success. Second, participants credited the processes of the procedure with harnessing the advantages of existing diversity. Last, participants connected the diversity and procedures with positive outcomes both in teamwork and their creative products (e.g., ideas, teams, projects).

Participants associated the presence of the right inputs (i.e., the diversity of ideas and people) with the process itself when they described the outcomes they witnessed. One participant remarked on the ways her diverse team coalesced and collaborated:

I think we have a lot of respect for our ideas even though we come from different backgrounds, and it just seems to really mesh well. I've definitely worked in groups when someone has an idea and someone has a very different idea... [On this team] when someone has a really good idea, we're all like, 'yeah, let me see what I can add to that.'

Her observations illustrate the productive dynamics in the team. Diversity, a potential source of conflict, is turned into an asset through congenial collaboration among teammates. We also note the fluid needs of executing oscillation present in statements like these (e.g., from divergence "someone has an idea and someone has a very different idea" to convergence "when someone has a really good idea... 'let me see what I can add to that'"). Diversity and differentiation (of ideas, people) requires careful alternation and at key moments. Creative processes must pivot during crucial periods ("when [emphasis added] someone has a really good idea") for them to be effectively utilized.

Accordingly, the sequencing of activities themselves was roundly credited as playing a role in how participants explained their own short- and long-term outcomes. For example, one participant recounted how the activities built on one another during a workshop, and how he perceived the process as leveraging ideas out of diversity:

[We] go into a room, we start talking about who we are, where we're from, what our favorite song is. These sorts of things... building up to... in the same room, in the same

group of people, hashing out ideas, putting it on butcher paper just to get it up, saying “what do you think of this?” Deliberating on the ideas, reconvening, and coming back to offer critique and comment... All leading up to something concrete that we could walk away from with an understood division of labor and a target.

The participant viewed the procedure as enabling his team to produce something concrete from a room full of people with different questions, interests, and perspectives. We believe he implicitly described oscillation as a key component of this process in his discussion of the role of “deliberating on ideas” (divergence), “reconvening” (convergence), and “critique” (divergence). Moreover, he highlighted the value of concluding with a period of convergence and commitment to produce something “concrete.”

These comments suggest participants connected these outcomes—diversity and the final projects—with the experience of oscillation. These comments also evince that it was not just the presence of the right ingredients (diversity) but that creative processes’ sequencing and timing were crucial to these inputs being effectively utilized. Further, participants went beyond recognizing the jumble of activities as constructive, but consistently recounted the *changes* in different styles of work at certain moments as positive contributors.

Perceived uncertainty. Further evidence of oscillation emerged in recurring descriptions of uncertainty during moments of transition between divergent and convergent activities.

Uncertainty took the form of questions of *how* or *when* ideas and teams could come together.

Participants paired uncertainty with feelings of ambiguity and discomfort as they wondered how these people, ideas, or projects would fit with one another. One moment when this was visible emerged as organizers led participants through a nominal group technique (NGT; Delbecq, Van de Ven, & Gustafson, 1975) procedure during day 1 of the first workshop. The NGT begins with structured brainstorming, whereby participants silently list potential ideas regarding a prompt, and then serially list these ideas on a joint display. This divergent procedure was designed to

elicit the participants' differentiated perspectives before they moved to later steps of integration in the NGT in which they collapsed, combined, or discussed ideas. At its core, the NGT purposefully cultivates an episode of alternation from differentiation into integration, and thus provided a rich opportunity to solicit participant experiences of this process.

At this juncture in particular, participants both registered positive reactions to and relayed discomfort at the open direction of the activity. Expressing reservations about the process as they reflected on the sheer number of ideas before them, one participant stated in a comment, "I appreciate the open direction and enjoy it. However, I would prefer to have some more direction..." We believe these "but" statements ("I appreciate... [h]owever...") reflect the differentiation-integration tension. Per our framework, differentiation should be followed by integration; a "jumble" of ideas can only serve as a resource from which to derive more focused, coherent projects. These statements highlight participant perceptions of a potential for convergence ("I appreciate") while acknowledging the need for constructive criticism ("however").

After the NGT session, participants not only experienced uncertainty, but voiced a desire for further convergence. For example, one participant noted: "Many of these projects have similar overlaps... it would be good to consolidate ideas so we are not all working in parallel... or maybe this is good?" Participants wanted to begin consolidating and refining what they saw as a broad array of disparate ideas. Indeed, before the start of the next activity where participants would begin to integrate individuals' ideas, a participant commented positively on how people were beginning to collect around different themes. But, in a later interview, he recalled his thoughts at the time: "how is this going to all work out?" That participants felt the need for

integration in the face of multiple ideas underscores the consequences of the differentiation-integration tension.

These excerpts track what we expected to be the participants' reactions: Divergence should foster uncertainty because groups will have difficulty seeing connections among ideas (Georgiev & Gorgiev, 2018; Cropley, 2006). This uncertainty should create a need for the team to decide which ideas—or combination of ideas—to converge on and move forward with. One participant described the initial series of divergent procedures as “in some ways putting the cart before the horse,” expressing his sense that a project should start with a shared goal and then generate divergent ideas on how to achieve it. The framework required at times radical periods of divergence in order to maximize the advantages of diversity, but this led, necessarily, to unclear and multitudinous paths moving forward. Together, these data suggest that not only did the design produce this discomfort, but participants noticed and experienced it. Taken with the context under which these comments were made, participants may have been sensing that a style of work (divergent or convergent) was beginning to lose its positive effects. Indeed, participants most often expressed uncertainty in those moments that our framework might suggest that continued over-divergence or over-convergence would rapidly begin to be unproductive. To manage participant reactions to the differentiation-integration tension, the procedure must promote a fine, and well-timed, balance between the two, as we see in the third theme.

A balancing act. As teams shifted into the divergent work period following the first workshop, participants expressed a growing perception of their projects as a balancing act. Teams felt they needed the flexibility to value differing expertise and the focus to consolidate diverse knowledge into an actionable set of creative ideas. One participant identified achieving balance as an inherent challenge: “You have asked us to find a team, coming from different

disciplines—knowledge from different disciplines that can lead the team. Each person has their own expertise and finding the common ground among the different teams is hard right now.” To be successful, teams felt they must balance a plurality of differences while also finding productive common ground.

Another participant noted that success in these conditions required flexibility to balance the team’s contrasting needs. Progress on his team had slowed to a frustrating level, and in his interview, he noted one area in which he felt his team could have done better. He said:

The balance [on teamwork] is allowing as much flexibility as you can at the local level. What are the areas we can agree on, what are those we have strong preferences on? If we all have different things that are all interesting at a local level, let’s all explore those and come together and share on our localized research. We don’t all have to be investigating the exact same thing because different things are all important to us in different places. And maybe there’s something to be learned from that.

That he notes this tension (“the balance”) as well as the ways in which his team must manage it (e.g., having “flexibility” in exploring things individually before reconvening and integrating) suggests this participant saw the procedure as highlighting the dual pulls of differentiation and integration. To participants, the procedure is suggesting a method to both value and manage the pulls of integration and differentiation

In sum, these data suggest that participants experienced oscillation in a few notable ways during the procedure. Participants associated the oscillatory process with the successes they saw, experienced moments of uncertainty resulting from oscillation, and came to view their own work as a balance between competing needs. But how did this procedure whose design was guided by our framework affect team outcomes like creativity? We explore this question in the following section.

Procedural Impacts on Creative Products

That participants credited the procedure as facilitating their generation of teams and projects serves as initial evidence that a procedure designed under the auspices of oscillation can be effective. Our second research question centers on an exploratory assessment of how oscillation positively impacted team outcomes. We now turn to products of our procedure to address this question more fully. If the procedure facilitated creative ideas, the teams' products (i.e., documents like project summaries) should be more creative than comparable products made outside of the procedure. Our assessment serves as an initial indication of potential outcomes of an oscillating process as presented above, rather than a standalone measurement of team success.

We used a creativity assessment technique (CAT) developed by Amabile (1996) to evaluate the creativity of the projects generated by the teams compared to projects related to climate resilience currently funded by the National Science Foundation (NSF). CAT involves presenting the products to be judged to a group of domain-familiar experts. In our study, the products were NSF-style two-page summaries of research projects: two generated in our workshops and five randomly selected from comparable, already funded NSF projects on climate resilience. The judges evaluated each product along three dimensions: novelty, feasibility, and impact. Amabile (1996) included novelty and feasibility as dimensions of her creativity construct. We added impact as a third dimension based on the NSF's criteria for creative work addressing grand challenges (National Science Foundation, 2014).

We employed a two-step selection process in which the members of the research team first rated the project summaries for the five teams on the creativity scales. We selected the two highest rated summaries to submit to the expert judges. Pre-selection of a subset of our proposals helped reduce fatigue on the judges (see Einhorn, Hogarth, & Klempner, 1977) and provided a fairer comparison with high-quality, funded projects. Given that the NSF has historically had a

proposal success rate between 20% to 30%, we reasoned using our two highest performing proposals would sufficiently mirror this rate while still allowing us to assess multiple projects.

To provide comparison with existing climate resilience research, we sampled five project descriptions that received funding from NSF from a sampling frame of 3000 summaries retrieved from NSF Fastlane. Our initial sample consisted of grants currently under award that included the keywords “climate resili*”, “mitigat*”, “adapt*”, “sustain*” in their title or project summary. We reduced the sample to include only projects addressing social consequences through changes or developments in infrastructure, science, engineering, or technology. For renewals, we kept the most recent iteration of the proposal and excluded grants with more than \$1 million in funding. Last, we removed all doctoral dissertations. Our rationale for these choices was to make our ground comparison cases as similar as possible to the projects generated by our groups. This reduced the sample to 330 projects, from which we took a random sample of five summaries to serve as a comparison for analysis. Next, we asked six subject matter experts (four assistant or associate professors, a doctoral candidate, and a climate specialist from a tribal college) to rate each of the seven project descriptions on nine items that measure the three dimensions of creativity. Data were collected through an online survey that anonymized the projects and gave no indication which were generated by our project teams and which were funded NSF projects.

Interrater agreement for ratings on the projects was assessed using the intraclass correlation measure for exact agreement among raters (ICC2). A significant test for this measure indicates that agreement among raters is adequate, and the value of the coefficient gives an indication of the degree of agreement. For all scales the ICC2 was significant, with values ranging from .95 to .39 (see Table 1). Raters had high levels of agreement on five projects, but there was some level of disagreement for two of the projects. Because creativity is domain-

specific, Amabile's (1996) CAT argues for the use of interrater agreement as the primary criterion of validity. We aggregated the creativity scores across the three dimensions, to give an overall index of creativity. The two project summaries created by teams using our procedure had mean total creativity scores of 49.33 and 56.17, respectively, out of a possible score of 63. These scores were on par with those of funded NSF projects, which ranged from 46.67 to 59.4; projects generated using our procedure ranked 2nd and 6th respectively of the seven projects rated. These results indicate that the projects generated from the procedure were at least as creative as currently funded NSF research.

[Insert Table 1 about here]

These findings suggest the oscillatory procedure facilitated the teams' production of creative products. Further indicators support that the teams' work was productive. Team dynamics are also a useful indicator of team success. In regards to team-level effectiveness, participants rated their teams highly in measures of team efficacy (rated 1-5, with 1 indicating low efficacy and 5 indicating high efficacy; $M = 4.43$, $SD = .47$, $n = 15$) and group cohesion (rated 1-5, with 1 indicating low cohesion and 5 indicating high cohesion; $M = 4.43$, $SD = .45$, $n = 15$) in post-workshop questionnaires. Additional evidence of effectiveness comes from the results of the workshops. The procedure was clearly productive in terms of ideas. At the conclusion of the first workshop, participants had generated 125 unique research problems addressing climate change resilience. The first workshop resulted in nine potential research projects, from which the teams selected five for further development. Two of these eventuated in full proposals and one team's project was selected for funding through a competitive review by the Environmental Protection Agency. Our assessment yielded initial indication of positive

outcomes for our participant teams. We now turn to refocus on the theoretical process identified in this paper.

Discussion and Conclusions

The paper has described a fundamental tension between integration and differentiation in creative, diverse teamwork. We explored a strategy to foster creativity by oscillating between divergent and convergent activities, thereby accessing states of differentiation and integration. By alternating between these states over time, teams oscillate between each pole in order to facilitate creativity. Findings from our case study supported that the proposed strategy generated differentiation and integration through alternating between convergence and divergence. In exploring Research Question 1, we found three main themes emergent in our interview and free response survey data: participant accounts that (a) divergence/convergence oscillations were key drivers in team processes and successes, which (b) required managing forces resultant from diversity while utilizing its necessary advantages, and (c) incited feelings of discomfort and uncertainty, particularly during moments of transition.

Regarding Research Question 2, creativity ratings and outcomes of project development provided evidence that the oscillatory strategy facilitated the generation of creative teams and projects. Findings from the creativity assessment indicated that the projects generated from the strategy were as creative as funded NSF projects in the same domain. In addition, the conclusion of the first workshop saw the development of diverse teams that scored highly on measures of team efficacy and cohesion. Finally, at least one project was approved for funding by a major research funding agency.

There are several strengths to the design of this study. First, the teams were observed closely over time, which allowed us to track the procedure and the effects of the procedure on the

team processes in detail. Second, researchers collected subjective and objective data through interviews, open-responses, and observations. Although we are not able to make claims of causality, the breadth of data gave us a strong foundation of participant experience and perception of oscillation. Similarly, the products of the procedure were assessed by domain experts, which lent external validity to the findings on creativity. Third, we employed and tested the theoretical framework in practice with bona fide science teams. As a result, we could assess the procedure in an applied context where teams and individuals faced, and overcame, external barriers that mirror experiences from the real-world practice of team science.

Theoretical and Practical Implications

A key element of our procedural framework is that it supported the entire creative process—from team formation to proposal development—rather than just offering support for one or two phases of the process, which responds to recent calls for more dynamic, temporal perspectives on how diverse teams work (Guillame et al., 2014; Van Dyke et al., 2017). Our results suggest that participants were satisfied with the results of the first workshop in which they identified promising projects and formed into research teams with common interests. Rather than focusing on a single event, we were able to look at creativity as an iterative process over time and we showed value in this approach. As our interview and real-time data indicated, our participants attributed the ongoing engagement of the procedure as a key contributor to their ultimate productivity.

Regarding a more dynamic perspective, our findings suggested that—just like simply increasing diversity is insufficient for greater creativity (Van Knippenberg & However, 2017)—simply taking teams through a prescribed series of convergent and divergent activities is not the sole ingredient to team success. Participant accounts evinced that it was often the careful

sequence and reflexive timing of procedures that they perceived as most useful. Our analysis suggests that perceptions of uncertainty might be indicators of the team's need to "tack"—either from divergence to convergence or vice versa. Uncertainty (and its resolution) might be an important generative experience in the alternation approach we have provided, despite uncertainty's deleterious potential in team innovation (De Clercq, 2019). It is not enough to just tack—rather, teams must tack at the right moments. These findings suggest that any managerial guidance through these procedures must be sensitive to and reflexive about ongoing team processes.

We provide evidence that builds on why fluid, context-specific procedures designed on the auspices of oscillation have promise when applied to creative work on diverse teams. We have developed a framework that is internally referent to process and interrogated not only what shifts to make but when to make them. Indeed, as we found, a consistent theme that cut across our qualitative findings was that sequence, timing, and sensitivity to process matters. We have argued that oscillation is important and have begun to identify signals for when "tacking" is necessary. Thus, a key conclusion is that procedures for intervening should strive to be reactive and reflective rather than prescriptive (and doubly so given that diversity presents and manifests itself in a multitude of context-specific ways; Poole, 2013).

Next, by tracking and guiding the teams through the entire months-long creativity process, we were able to both observe the processes at play and increase claims of external validity. This study finds evidence that taking a processual and longitudinal approach to team science is both valid and necessary if we are to design interventions that faithfully support the reality of teamwork. Each team in this project experienced conflicts and tensions during the

gestation period, and many participants credited the longitudinal support of the procedure and of their cohort as one of the key facilitators to their continued engagement.

We also found evidence for the differentiation-integration tension. The findings suggested that not only did oscillation occur through alternating procedures of divergence and convergence, but that the measured and repeated switching between differentiating and integrating tasks was effective in fostering creativity. We proposed that differentiation and integration were communication processes that exist fundamentally in tension with each other. Each effort that produces benefits also produces challenges that counterpose the other. This work supports the notion that, like most tensions, differentiation-integration should not be treated as reconcilable but instead as something to be continually managed. This suggests the way we think about interventions and group processes should shift to a more open, dialectical process wherein diversity is not an issue to be *solved* through integration but instead be in conversation with it. This claim aligns with similar calls that organizational actors adopt “a paradox lens” in innovation and creativity (Liu, Xu, Zhang, 2019, p. 361).

It is worth noting that although our study has focused on the tension between differentiation and integration, we are not claiming that this is the *only* tension that diverse teams face as they collaborate. As Poole (2013) has argued, diverse collaborations are characterized by multiple complex tensions by their very nature. For example, teams face the need to balance individual-level goals and collective goals, to balance structured action while allowing for emergent findings, and to balance a value for individual expertise while seeking to understand partners’ knowledge. Given our initial evidence that a strategy of oscillation was effective at addressing one tension, our study provides support for the claim that interventions designed to address tensions through a tactic of alternation might be particularly effective in these contexts as

well. Clearly, further research will be required to assess whether this is the case. Future work should also consider testing oscillatory procedures on the logic of a field experimental design.

Despite the uniformly positive feedback and promising performance outcomes, the procedure is not a panacea for the challenges of diversity on teams. Although our cohort generated five project teams from a cohort of seventeen strangers, only two of those teams successfully produced proposals for a funding agency. Those other three teams eventually disbanded due to a varied set of factors ranging from individual differences, institutional pressures, and the challenges of working on geographically distributed teams. Clearly, further research is needed to examine the uniquely compounding nature of the social barriers inhibiting group processes on diverse teams.

Further, the current analysis focused specifically on how the adoption of an oscillation strategy influenced teams' experiences managing the challenges of informational diversity. Informational diversity is but one of many forms of difference that can influence team dynamics (van Knippenberg & Mell, 2016). Given that our participants represented a variety of institutions serving historically underserved populations, our data also include rich accounts of the challenges faced when seeking to collaborate across organizations with different institutional positions such as group identity (Crary, 2017), functional diversity (Zhang, 2016), or institutional diversity (Clark, 2010). In another analysis, currently underway, we are exploring our participants' experiences of barriers that emerged as a result of other forms of diversity, and the tactics they deployed to manage those barriers.

Finally, this work has direct implications for agencies and organizations that are interested in developing and funding creative research teams and projects. One clear applied implication of this work is the implication that organizations might consider investing resources

in enabling and expecting process work that clearly incentivizes (and maximize the potential of) diverse teamwork through oscillation. For example, most agencies require researchers to include a project description that outlines the intellectual merit, research design, and procedures for accomplishing proposed outcomes in their grant proposals. Organizations interested in facilitating creative success on diverse teams might consider requiring proposers to specifically outline in this section the techniques they will use to foster the ongoing exchange and production of knowledge on interdisciplinary teams. If making this an explicit requirement were deemed too onerous, it still might be useful to include an assessment of proposed team processes as an important component of the selection process for interdisciplinary research projects.

Practitioners can consider applying structured interventions that facilitate longitudinal engagement and support, especially on diverse teams. Policymakers have increasingly recognized that diverse teams are necessary to address many grand-challenge problems in science such as climate change, food and water security, and energy sustainability (Committee on Key Challenge Areas for Convergence and Health, 2014). This assertion is supported by findings from the science of team science, which suggests that, when successful, diverse teams can be a well-spring of innovation across the boundaries of scientific fields. Our project demonstrates that simply getting a diverse cohort of individuals in the room is a necessary, but likely insufficient requirement to sparking successful diversity in science. Indeed, other research shows that most attempts at building diverse teams in science fail (Leahey, 2017). This project suggests that mitigating these challenges will require organizations to develop longitudinal support structures that actively cultivate oscillatory processes on nascent scientific teams.

This study has several limitations. Longitudinal study of teams is time and resource intensive, which limited the number of participants we were able to support and study over six

months. We were limited by a small number of teams with which to assess our process, and therefore by a small number of project proposals to use as outcome measures. Further, this project focuses on the outcomes of a single instance of procedural intervention. What this work lacks in numbers, however, is made up for in an in-depth case study that applies a theoretical model to real, interdisciplinary science teams. Although the findings are encouraging, replication with multiple cohorts will be important to validate and extend conclusions about the procedure. Furthermore, as our workshops focused on the creation of grant proposals for real science teams, our research team had to take care to not become overly involved with the “fates” of our subject teams. To mitigate this risk, the research team took intentional steps to externally validate and analyze the data collected (including external judges for creativity assessments and embargoing data from research members involved in organizing). In these ways we limited our biases, but it remains possible our interest in the teams’ success had some impact.

To conclude, we provide an overall structure of oscillation, shifting between divergence and convergence, as one exemplar for both researchers and practitioners to build from (see appendix). Although the particulars of our procedure can easily (and should) be altered to fit the needs of individual contexts, we believe that our overarching structure of oscillation over time, between integration and differentiation, knits together a promising theoretical understanding of diversity and creativity.

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Figures

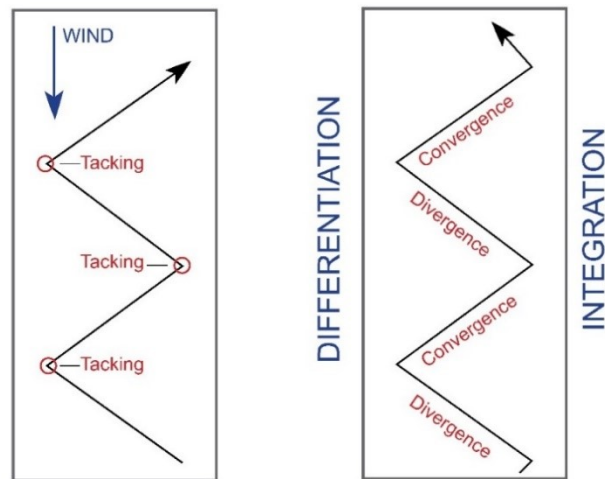


Figure 1. Tacking in a sailboat (left) and the oscillatory procedural framework (right), whereby teams undergo periods of divergence (which emphasize differentiation) and convergence (which emphasize integration)

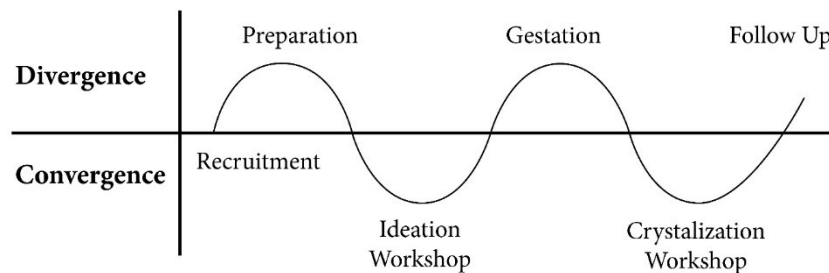


Figure 2. The longitudinal oscillations between periods of divergence and convergence through the entire length of the procedure.

Tables

Table 1.

Reliability of Project Ratings

Ratings	Cronbach's Alpha	ICC Average Measure
1. Prep Engs	.948	.951*
2. Emp Comm	.856	.845*
3. Sim Plat	.858	.875*
4. En Loc Comm	.826	.812*
5. Drought Pred	.959	.943*
6. Change Narr	.379	.392*
7. Delto Co	.408	.401*

* $p < .05$

Appendix A

Creativity Measure

Please rate this project on each of the following criteria. Remember, we want you to use this set of 7 projects as your frame of reference for making a judgment on each criterion. Use your own subjective definition for each criterion. You are encouraged to make use of the entire scale.

The degree to which the project shows a **novel approach**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **technically achievable**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project demonstrates **potential for making an impact**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **socially beneficial**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **workable**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **creative**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **feasible**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **important**

(Low) 1 2 3 4 5 6 7 8 9 (High)

The degree to which the project is **original**

(Low) 1 2 3 4 5 6 7 8 9 (High)

Online Appendix B

Abridged Agenda for Idea Generation Workshop

Day 0 - Arrivals

Time	Section	Description	Research Annotations
4:00-	<i>Arrivals</i>	Participants arrive at local airport	
6:30	<i>Dinner</i>	Participants self-organize in lobby for dinner	Convergence: An initial opportunity for participants to get to know each other informally, in order to discover common ground.

Day 1 - Generating Connections, Problems, and Solutions

Time	Section	Description	Research Annotations
7:00	<i>Breakfast</i>	Hotel provided	
8:00	<i>Shuttle departs</i>	Pick-up at front door of hotel	
8:15	<i>Arrival at Conference Venue</i>	Arrive, registration, badges, settling in	Divergence: Individual participants have prepared a poster ahead of the workshop that illuminating their perspective toward the grand challenge of climate change. These posters are posted around the room upon arrival to initially highlight differing perspectives toward the research problem.
8:30-9:15	<i>Introductions</i>	Participants gather for introductions. Project team motivates workshop with research driven discussion about the strengths & challenges of transdisciplinarity. Initial round-robin of introductions.	Convergence: Round robin introductions facilitate initial awareness of others' knowledge.
9:15-10:30	<i>Illuminating our own perspectives and experiences</i>	We devote time to revealing each participant's background and expertise in relation to climate resilience. • 5 minute introduction to task • Lightning talks: Speakers have 2 minutes to introduce themselves and their research interests. • Partner Activity: Participants find partner and circulate the room together looking at other people's posters. Objective is to understand individuals' motivations for attending a workshop like this. • Report out: Group discussion identifying themes in motivating factors	Divergence: Lightning talks encourage participants to become aware of differing expertise and values represented among members of the cohort. Convergence: Partnering with a randomly selected individual and circulating the room helps create dyadic connections among cohort members. It also works to develop a shared understanding of motivations driving individuals to participate in the workshop. Group report out further solidifies the identification of common themes among participants' motivations for joining the workshop.
10:30 - 10:45	<i>Break</i>		Participants are encouraged to browse posters on the walls to familiarize with their peers' expertise
10:45 - 11:45	<i>Finding Balance on</i>	A guided discussion about balancing individual needs with finding common ground.	Divergence: Reflecting on individual needs, such as publication requirements, targeted funding agencies, and promotion & tenure criteria,

	<i>Diverse Teams</i>	10 minute introduction: The goal here is to form innovative projects, but it is also to make sure that things are tenable. But, we also need to be aware of motivating factors Pairs – find someone else to work with: Brainstorm the <i>outputs, deliverables, and other requirements</i> that will need to be present in order for you to actively sustain engagement on a research project. Group Discussion – what are some of the things that you need in order to participate? Organizers record themes on a flip chart, post on a wall	illuminates the diversity of contexts from which participants hail. Convergence: Group discussion of individual needs emphasizes themes among participants. Posting these themes on the wall permits a persistent display that is uniformly available for reference for the remainder of the workshop.
12:00	<i>Working lunch/ Introductory Panel to Climate Resilience Research</i>	2-3 Representatives who are situated within current research/policy environment comment on their perspectives on the grand-challenge of Resilience to Climate Change	
1:00-2:45	<i>Generating Problems/Gaps/Challenges</i>	Using Nominal Group Technique for two 5 person heterogeneous groups, address the question: “What are the major problems, challenges, and gaps in understanding and promoting resilience to climate change?” - Assign teams – go to the table without the person who you partnered with during sticker activity 1. Divide into two heterogeneous groups (can’t be in the group with the person you were paired with) - Activity Introduction [10 minutes] 10 minutes of silent idea generation - Round robin listing ideas (15-20 minutes) - Briefly clarify each idea (10 minutes) - Sanction the group – we’re not arguing points - Idea Ratings (10 minutes) - Pick your top 5 ideas, order them from one to five in terms of “how important are these gaps” - Short Break while facilitator tabulates (10 minutes)	Divergence: Assigning participants to partners they have not yet discourages them for forming factions early in the procedure. Silent idea generation draws upon a social facilitation effect to encourage productivity while maximizing individual difference in brainstorming potential problems to be addressed. Round-robin listing avoids over-representing any individual’s perspectives during the idea generation phase of the process. Convergence: Clarifying ideas, while sanctioning debate, encourages a common understanding of the pool without allowing the group to converge too quickly upon any single solution. Divergence: Individual voting emphasizes each participants’ initial valuations of the problem space. Convergence: Tabulating results and consolidating the list begins to remove individual authorship from ideas. Focuses the group on a common set of shared issues. Anonymous ratings serves to de-individualize ownership of ideas. Open group discussion serves to further consolidate issues as the group selects 5-8 core issues that they see as most important to them.

		• Regroup and consolidate into smallest list possible (20 minutes) • Discuss each idea in more depth (20 minutes) ◦ Why do you think this is important? What could it lead do/ • Sticker ranking (5 minutes) - 3 stickers to put by the ideas that you think are the most important.	Discussion and elaboration of these ideas helps specify the aspect of the issue with shared interest. Divergence: a final round of sticker voting helps to anonymously reveal which issues have the most support for moving forward.
2:45-3:30	<i>Extended Break</i>	During break: Facilitators prepare fresh charts listing the final ideas for each of the two NGT groups. Set charts up in the front of the room (6-12 sheets of paper)	
3:30-4:15	<i>Freeform discussion and ranking by entire group</i>	Each group reports their rankings to the community. • Facilitators each report out on the selected ideas (hopefully 6-7 from each group) asking group to clarify if they've missed anything. [15 minutes] • Group discussion: [20 min] Which of these ideas seem to link to each other? Can any of these potential problems be collapsed together? What themes do you notice? Connections to our earlier discussions? • Final Voting activity: [10] Participants write their names next to the problems that they are excited and interested in building a project to address.	Divergence: Describing the key themes from each of the two NGT groups helps to broaden each nominal group's perspectives on the key issues to addressing the grand-challenge. Convergence: The group discussion serves to find connections and commonalities between ideas developed by each of the two nominal groups. Encouraging connections serves to further connect individuals in the room. Asking individuals to write their names next to the problems they would be interested in building a project around serves to identify potential collaborators in the room. The fact that this is the first visible commitment serves symbolically to help participants see <i>who</i> in the cohort might make an potential collaborator for a project.
4:15-5:15	<i>Intra-stakeholder Reflection</i>	Members meet in four homogeneous groups and discuss what was left out, from the point of view of their perspective. These groups report to the community as a whole and potentially amend project ideas accordingly.	Divergence: encouraging participants to openly discuss the differing climates within which they work serves to illuminate the varying perspectives, resources, and requirements for individuals participating in ongoing projects.
5:15	<i>Concluding Discussion</i>	Convene entire group to do a system checkup in which they process the day, what worked and what did not, and indicate what ideas they find most promising. The project team shares a research-driven justification for <i>why</i> the day was structured as such.	
5:30	<i>Transportation to Dinner</i>		
6:30	<i>Dinner</i>	Working Dinner Presentation/Discussion: Using the Science of Team-Science to Collaborate Co-organizers give a brief presentation summarizing some key-findings for groups and teams research with an emphasis on understanding the common challenges faced by diverse teams collaborating at a distance. The talk emphasizes theory proven tactics that teams may adopt if they wish to address these issues.	Convergence: Individuals are encouraged to share a meal with individuals who marked their names next to the same themes as themselves. Dinner serves as an informal opportunity to begin thinking about potential collaborations.

Day 2 - Project Ideation

Time	Section	Description	Annotations
7:00	<i>Breakfast at hotel</i>		
8:00	<i>Shuttle departs</i>		
8:15	<i>Arrival at conference venue</i>		Key Challenges from Day-1 are posted visibly on the wall around the room.
8:30	<i>Project Generation</i>	A stepladder process is used to generate projects addressing the problems/challenges/gaps from yesterday's lists. Participants think individually, then meet with one other person to trade ideas, pairs join for discussion, then fours join into eights. Each person individually distills one or more project ideas, putting them on a display. Organizers set up a ground rule that no criticism of potential projects will be allowed during this activity. We encourage participants to start a new project idea if they have a criticism. 16 participants are assigned seats at 4-person tables one of the key themes they signed up for yesterday written on a paper pad in front of them. They sit next to an individual who indicated the same issue, and across from a pair of individuals who will be working on a different issue. Part 1: (10-minutes) Individually brainstorm 1-2 ideas for a project addressing the challenge that you've been assigned. Make sure to explain <i>how</i> your project addresses the problem. Make sure that each idea is on a separate sheet of paper Part 2: Pair up with your neighbor, who has been working on project ideas addressing the same problem. Each spend 10 minutes describing your project ideas [10 minutes]. Swap papers and silently either elaborate or make a new project [5 minutes] De-brief by briefly sharing your new contributions [5 minutes] Part 3 (30 minutes total): Groups of 4 across the table Briefly describe each project-let with the goal of elaborating as a team. If you come up with any new project-lets make sure you write them down on their own separate sheet.	Divergence: Setting up a norm of sanctioning criticism helps ensure that individual ideas will be heard and elaborated upon. The initial period of silent ideation serves to generate as many potential methods/techniques as possible for addressing each of the challenges from the preceding day. Convergence: Sharing ideas with a partner serves to help individuals find common ground with a participant who is passionate about a similar issue. Having these partners physically swap their papers serves for the next step of elaboration serves to de-individualize the authorship. Divergence: The second round of silent elaboration serves to further diversify the perspectives on each grand challenge issues. Divergence: Asking each pair to share and elaborate their nascent project ideas with a pair that has been working on a different problem serves to widen the perspectives attending to each issue. Convergence: As teams shift into specifying their elaborations to their problems, they connect their ideas together into the beginnings of cohesive ideas. Divergence: As teams finish their activities, they post their project ideas on the flip chart naming their grand challenge. They then circulate the room to familiarize themselves with the ideas developed throughout the other tables' exercise.
10:00	<i>Coffee Break</i>		
10:15-10:45	<i>Project Conversations</i>	Members circulate among displays in pairs and discuss possibilities. They switch partners and continue the process until they have discussed some possibilities with three other participants. Areas of overlap among individual ideas are identified.	Divergence: Asking teams to circulate the room exposed each participant to the breadth of ideas developed during the morning's exercise. Convergence: Asking participants to circulate and discuss with multiple partners helps to form

			social connections. Charging each dyad with finding overlap in ideas serves to help consolidate ideas into emergent themes.
10:45	<i>Ideation Round 1</i>	Members self-select to work on project ideas subject to these rules: Each group around an idea must have members from more than one institution and stakeholder group. Groups must be 3 or more members initially. Groups describe projects on flip charts The goal is to start integrating project-lets into early ideas for projects that address the problem. Each emergent team chooses one of the problems of their liking and spend the next 50 minutes designing a project that will address that problem. Teams are told they need to nominate a presenter to share their project with the group during lunch.	Convergence: Asking individuals to begin specifying projects around one of the challenges serves to encourage integration of the wide number of ideas developed in the morning's activities. Asking the team to present creates a social pressure encouraging consolidation and specificity in the project.
11:45	<i>Working lunch/panel; groups from morning sit together</i>	Each group explains its ideas to the larger group. No criticism is allowed, only questions. Members of larger groups write questions/comments on cards and share with project group, which digests and acts on it. Experts will be present to meet with each group and give their own ideas and reactions. Each team presents their project [10 minutes each] Clarification questions are encouraged. As you listen, write down reactions to the project on notecards. These can include additional ideas, possible negative points, things that need clarification. Note which project you're commenting on the card (Color coded cards)	Divergence: As teams present their nascent project ideas, the rest of the cohort offers initial rough feedback and elaboration. These perspectives serve to widen the vantage of expertise on each proto-project.
1:00-1:30	<i>Consolidation Round 1</i>	Project groups separate to refine ideas in response to feedback from larger group.	Convergence: The same groups have an opportunity to integrate the feedback from lunch and record it on a shared display.
1:30-2:15	<i>Expert Panel 2</i>	A panel of experienced transdisciplinary researchers tells short stories about the challenges faced in <i>executing novel ideas on interdisciplinary teams</i> . The key emphasis here will be on the <i>practice</i> of working on diverse teams, in terms of their potential for benefit and the surprising challenges they have encountered in their experiences.	
2:15-3:00	<i>Break</i>		
3:00-5:30	<i>Rounds 2 of ideation & consolidation</i>	Members reform groups around another project idea and repeat steps of ideation process. Members must work on a different problem than the one that they focused on for ideation round 1, but they <i>may</i> develop a different project idea addressing one of the problems from the first round of ideation. Again, experts will be	Divergence: Forcing individuals to elaborate on a second project with different participants discourages early commitment to projects from the morning.

		present to meet with each group and give ideas and reactions.	Convergence/Divergence/Convergence: The remainder of the process continues as the session preceding lunch. Convergence: At the end of this session, project ideas are all posted on shared displays around the room. Individuals are asked to write their names next to 2-3 projects that they might be interested in committing to work on the following day.
5:30	<i>Shuttle departs</i>	Depart for Hotel	
5:45	<i>Arrival at hotel</i>	Participants have a short break before dinner.	
6:30	<i>Dinner Big Grove Tavern</i>	Working dinner discussion: Focuses on the realities of group work. Each table of participants is given a case analysis exercise about a team that has encountered one of the many challenges that emerge on diverse teams (e.g. differing objectives, competing demands for time, etc.).	Convergence: Individuals are encouraged to sit with participants who have indicated preferences for similar project ideas. This serves as another informal opportunity to begin to form common-ground. The evening's activity also serves to create common-ground about the specific tactics that the team will employ to recognize and address any social barriers they will encounter over the ensuing months working together.

Day 3: Work Planning/Conclusion

Time	Section	Description	Research Annotations
7:45a	<i>Shuttle departs for convergence venue</i>		
8:00	<i>Introduction to final day, Discussion of the collaboration process</i>	Project team discusses the goal for the day: to self-organize into teams around specific projects and to develop actionable plans for moving forward in their development over the following 3 months.	
8:30-9:45	<i>Team Selection</i>	The whole group convenes to revisit prior day's projects, and then members indicate individual project rankings by "dot voting" where they are given dot stickers and then they "vote" for projects by putting stickers by the project on the flip chart. Ranks are aggregated to give a sense of promising directions. Members divide into working groups. We have project teams from yesterday spend 4 minutes reminding us of the key ideas for each of the projects. Participants put stickers on projects that meet the following criteria:	Convergence: Describing each project serves to build common understanding of the directions defined during yesterday's activities. Divergence: Anonymous sticker voting serves to reveal the latent differences in value for each of the proto-projects. Convergence: Asking individuals to write their names next to the 1-project they wish to pursue serves as a final indicator of group-membership.

		1) You believe they are important 2) You are actively interested in being involved in their execution 3) You believe others at the workshop will be interested in them as well These four projects got a significant interest. Now, go and write your name on 1 of them. - Go through each project and discuss the team. - o Is it diverse? - o What different expertise to people bring to the project? - o What expertise do they see as potentially missing?	At this point in the process, the cohort will have formally identified its project teams for the ensuing months.
9:45-10:00	<i>Break</i>		
10:00-11:30	<i>Project Planning Discussions</i>	Project groups meet individually to plan out the <i>process</i> by which they will revise, refine, and develop their project idea over the following three months. Two main goals for this activity: 1) Begin roughing out your projects with ideas of what research you need to do to develop your ideas, how you plan to distribute tasks, methods you will need to incorporate, etc. 2) We want you to draft a team charter. It's a working document – but the goal is to have you engage in a discussion about your process and expectations for working together on teams.	Convergence: The newly formed teams fill out a formal “team charter” statement that describes their objectives, norms, rules, and meeting plans. They create a rough timeline of activities for the ensuing months. With about 15 minutes remaining in the session, participants are asked to report their charter out to the rest of the cohort.
11:30	<i>Workshop Reflection and distribution of sack lunches</i>	Project Team and Participants engage in dialogue about the workshop process emphasizing learnings, aspects that worked, and areas for potential improvement.	
12:00	<i>Conclusion</i>	Workshop officially concludes.	