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A case study of strategies for fostering international, interdisciplinary research

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Abstract Bringing together and successfully managing a highly interdisciplinary (ID) research team of socioeconomic, biophysical, and engineering scientists is highly challenging, particularly when that team includes 20 scientists and students across six countries. This paper reports on the results of evaluating the success of such a team as it studies the socioecological impacts of bioenergy development across the Americas. We find that the team has succeeded according to several different metrics. We demonstrate that the literature on accelerated sustainability transitions and small group team creation, development, and management holds valuable lessons for the success of ID teams.

Keywords Team science · Scientific team · Group work · Sustainability transitions · Transition management · Transdisciplinary

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Introduction

Professionals working in the environmental arena frequently need to work in interdisciplinary (ID) small groups or teams in order to integrate the variety of socioecological dimensions of environmental problems (e.g., Garner et al. 2013). In USA, many funding agencies, including the National Science Foundation, the Department of Energy, and the US Department of Agriculture, require scientists to work within ID teams to compete for specific grants. However, ID teams around the world continue to struggle to develop polished, compelling, and fully integrated products. Creating and managing any work team is challenging, but ID teams include the additional challenge of disciplinary heterogeneity.

Members of work groups have age, racial, class, gender, occupational, and educational characteristics. When members of a group share many of these characteristics, the group can be considered homogeneous. Homogeneous groups can be relatively easy to manage since their members share many attributes (Bowers et al. 2000; Campion et al. 1993; Cummings and Kiesler 2008; Harrison et al. 2002; Harrison et al. 1998; Stewart 2006; Webber and Donahue 2001). However, members of heterogeneous groups tend to have divergent values, beliefs, norms, identities, and experiences. As federal agencies learned when they diversified to meet changes in national priorities and comply with federal legal and diversity requirements, the management of diverse, or heterogeneous, groups was challenging (Choi and Rainey 2010; Gladstein 1984; Halvorsen 2001; McLeod et al. 1996). When working on projects that evoke professional core identities, such diversity can lead to conflict (Harrison et al. 1998; 2002).

On the other hand, homogeneous groups may not be as adaptive, creative, or flexible as diverse groups are (Barak 2013; Bowers et al. 2000; Halvorsen 2001; Harrison et al. 2002; McLeod et al. 1996). This may be particularly

important when organizations face complex problems, such as environmental challenges. In these cases, homogeneous groups may not contain the expertise to successfully solve the problem (Norris et al. 2015), and they often perform poorly on creative and intellectual tasks (Milliken and Martins 1996; Stokols et al. 2008b) However, heterogeneous groups often have difficulty developing the cohesion and shared goals, norms, beliefs, and values required to succeed (Bowers et al. 2000; Brewer 1999; Cummings and Kiesler 2008; Gladstein 1984; Harrison et al. 1998, 2002; McLeod et al. 1996). Therefore, the successful development and management of heterogeneous teams continues to confound many types of organizations, including those conducting scientific research (Barak 2013; Brewer 1999).

One way to "speed up" the transition toward ID research is to facilitate it (Accelerating and rescaling transitions to sustainability ARTS 2015) through sustainability journeys, interventions, or transitions (Garud and Gehman 2012; Markard et al. 2012; Schensul 2009). These strategies are ways to jump-start change in sociotechnical systems and shift them toward increased sustainability. These interventions can be carried out at multiple societal levels.

An intervention is an event or action that induces change at a specific period of time, with multiple actors (Garud and Gehman 2012; Markard et al. 2012; Schensul 2009). Sustainability, in this context, means lasting change at several levels, beyond the intervening event (intervention). The intervention literature builds on the comparative science approach that utilizes historical analysis and ID research in order to guide a lasting, participatory change in society (Markard et al. 2012; Schensul 2009). Sustainability transitions research focuses on policy and the governance of society and institutions as they move from one type of system (e.g., fossil fuel-based) to another (e.g., renewable energy-based) (Jørgensen 2012). There is a gap between empirical and theoretical policy research in the sustainability transitions literature (Jørgensen 2012).

Some researchers have been improving upon the sustainability transitions framework with a new research area called accelerated transitions (Accelerating and rescaling transitions to sustainability ARTS 2015). Similar to extant research on transitions, a consortium of researchers have been studying transitions at different levels of society in five cities to determine which are most successful (Accelerating and rescaling transitions to sustainability ARTS 2015; Markard et al. 2012). Accelerating and Rescaling Transitions to Sustainability (ARTS) ID research projects include policy development and innovative management strategies that engage actors at many levels as a way to advance societal sustainability.

Training people to perform better ID sustainability research is an example of a sustainability intervention, with a focus on synergistic linkages and interactions between different types of science all focused on solving sustainability problems (Garner et al. 2013; Hall and O'Rourke 2014). Current sociotechnical systems or regimes (Markard et al. 2012) that train disciplinary scientists generally focus primarily on training them to work in teams, publish, and contribute solely to do those disciplines. There are organizational and disciplinary norms, cultures, and reward structures comprising sociotechnical systems that ensure that most scientists stay on a unidisciplinary track. However, this prevents their working to successfully solve complex, multidimensional sustainability problems with societal and environmental roots and impacts. Thus, this sociotechnical system reinforces scientific approaches that impede the creation of science better able to solve sustainability problems.

Just as the sociotechnical systems that result in sustainability problems like climate change and environmental pollution result from interlocking systems that can be hard to change due to their institutionalized nature (Garud and Gehman 2012; Markard et al. 2012; Schensul 2009), scientific sociotechnical systems are difficult to change. Sustainability interventions and accelerated transitions can be one way to do this whether change is desired in a broader sociotechnical system causing climate change or a scientific sociotechnical system fostering primarily unidisciplinary scientific outputs (Garner et al. 2013; Hall and O'Rourke 2014). Markard et al. (2012) summarizes and synthesizes sustainability transitions as focusing on *changes in sociotechnical systems or regimes* through the provision of protected *niches* where people can risk change through *interventions* that disseminate novel technologies and/or *institutional changes*.

The ID teamwork training described in this paper shares many elements with the sustainability transitions (Markard et al. 2012) and ARTS-accelerated transitions project. Most notably, both intend to change sociotechnical systems. Our work also builds on past ID teamwork and improving on its best practices, similar to the way ARTS reiterates and translates successful projects from one city to another. Sustainability transitions theory can help to inform successful ID teamwork, and vice versa. The case we describe here is a good example of an attempt at an accelerated transition toward interdisciplinarity.

While we have worked in many different ID teams studying environmental problems, we focus here on our assessment of a scientific team composed of 20 socioeconomic (SE), biophysical (BP), and engineering scientists and students studying the socioecological impacts of bioenergy development across six countries in North and South America. Core funding for the project comes from the Inter-American Institute for Global Change Research (IAI) Coordinated Research Network 3 (CRN3) program. The project runs from 2014 to 2016.

Socioecological problems are notoriously "wicked," in that they are very complex and difficult to definitively solve and require that scientists and managers take an ID team approach to research and problem solving (see, for example, Batie 2008;

Batterman et al. 2009; Falkenmark and Rockström 2004; Freeman 2000; Jury and Vaux 2005; Lach et al. 2005; Nowak et al. 2006). These types of teams are inherently heterogeneous. Each discipline has specialized terms, scientific paradigms, and research strategies. For instance, BP scientists tend to rely more strongly on strict hypothesis testing and predictability than SE scientists do. Members from different disciplines also tend to have variant values, beliefs, and norms, making it more difficult to work towards shared group goals, identity, and structure, all of which are essential to successful small group work (Babbie 1993). Overcoming these challenges requires skills in ID teamwork and management, which can be fostered by drawing upon more than a decade of research in sustainability transitions and transition management.

Literature review

ID scientific research teams (hereafter ID teams) are small groups, typically ranging in size between 5 and 50 members (Brower 1996; Daily and Ehrlich 1999; Cummings and Kiesler 2007). Descriptions of the challenges of managing ID teams abound in the literature (see for example, Aboelela et al. 2007; Bracken and Oughton 2006; Daily and Ehrlich 1999; Harris et al. 2009), but there has been less exploration of successful development of ID teamwork skills and management as small groups (Cheruvelil et al. 2014; Hall and O'Rourke 2014; Klein 2008; Levi 2013; Mâsse et al. 2008; O'Rourke et al. 2013). This type of assessment is needed to develop more effective ID teams. Here we review existing literature on ID team development and then show how the emergent themes map to sustainability transitions theory establishing that sociotechnical change can occur through interventions focused on the dissemination of strategies for institutional change provided in protected niches that allow people to learn how to deploy these new strategies (Markard et al. 2012).

Much of the literature on groups focuses on the formation of the team, using both quantitative (e.g., Klug and Bagrow 2014; Milojević 2014; Taramasco et al. 2010) and qualitative (e.g., Babbie 1993; Levi 2013; Stokols et al. 2008b) approaches. Successful groups, including small groups and work or scientific teams, go through a developmental process. Babbie (1993) describes this as the development of shared structure (a common sense of individual positions within the group and behavioral norms associated with the positions and work, including shared language and concepts) and identity (seeing oneself as part of the group, having a shared sense of what the group is about). He explains that common goals bring people to the group and consequently are refined over time as members work together. Babbie (1993) also notes that sustained interaction is essential to the development of shared goals, identity, and structure.

Tuckman and Jensen (1977) refer to these stages as "forming, storming, norming, and performing." In "forming," the group is new and members are just beginning to learn about each other. This may lead to conflict, or "storming," as members challenge each other's beliefs about group goals, tasks, and norms. The process of "norming" describes the state where the group members come to develop shared norms and goals that allow them to move to the last stage of "performing" the work. To aid in this process, when new teams form, Levi (2013) suggests socializing members into the group, defining clear group objectives, and defining appropriate behavior for group members.

A number of authors have described the difficulties of ID science research team creation and management (Campbell 2005; Eigenbrode et al. 2007; Fazey et al. 2013; Goring et al. 2014; Lélé and Norgaard 2005; Morse et al. 2007; Roy et al. 2013). Some argue that these challenges can be reduced through highly selective choices of diverse team members (Balsiger 2004; Cheruvelil et al. 2014; Levi 2013). Not only must team members bring the scientific and technical skills needed to represent the key aspects of the research problem, but they also need strong interpersonal and teamwork skills to get through the delicate work of navigating disparate professional identities, boundaries, and norms. Additionally, a sense of being a select member of an important group can help build commitment to and identification with it (Chiocchio and Essiembre 2009; Levi 2013). Many studies indicate that teams with members who have high social sensitivity, deep emotional engagement, and a high degree of diversity tend to function well (Cheruvelil et al. 2014; Pentland 2012; Parker and Hackett 2012; Stokols et al. 2008b; Woolley et al. 2010). ID teams must go through the same developmental stages as other types of teams, with the added challenge of the "conceptualization" stage, where team members integrate their disciplinary perspectives and knowledge domains to address the target problem in innovative ways (Hall et al. 2012).

Developing a strong team requires significant effort and time (Daily and Ehrlich 1999; Bracken and Oughton 2006; Cummings and Kiesler 2008; Harrison et al. 2002; Levi 2013; Stokols et al. 2008a; 2008b). Levi (2013) estimates that about half the time spent together as a diverse technical or scientific team will be spent on developing as a unit, the other half on the "technical" work of developing a project and/or implementing it. Creating shared norms of respect, language, and critical thinking requires extensive time spent working together (Brower 1996). When crossing major disciplinary boundaries from, say, engineering to social sciences, small groups need a lot of time and work to develop shared problem definition, languages, and concepts (Bowers et al. 2000; Bracken and Oughton 2006; Hall and O'Rourke 2014; Harrison et al. 1998; 2002; Pennington et al. 2013; Stewart 2006; Webber and Donahue 2001). However, if team

members develop a shared, efficient process for their joint work, they can better overcome the challenges inherent in heterogeneity (Campion et al. 1993; Cummings and Kiesler 2008). Simple conceptual models and considerable redundancy in communication can aid this process (Pennington et al. 2013). Highly effective teams often show positive interdependence of team members, effective communication, and individual and group accountability (Cheruvelil et al. 2014).

Leadership is particularly important. Skilled leaders can attract and develop a talented set of diverse team members, leading them through processes that encourage their development into a cohesive team, creating a strong identity with the group and a deep commitment to its product (Levi 2013; Stokols et al. 2008a). Leaders with high levels of intelligence, self-confidence, educational status, task-relevant knowledge, and sensitivity to members' socioemotional needs are often shown to be most effective at managing teams (Bales 1999; House and Baetz 1990; Stokols et al. 2008b). It is important for leaders to reward individuals who are particularly productive—a simple recognition of their efforts can be powerful. A good ID team leader will work with the team to develop clear tasks and reasonable strategies and deadlines for accomplishing them. Working on an ID team requires patience and a willingness to be flexible as members are introduced to new scientific concepts and methods, perhaps coming from fields for which they had little respect or understanding. A strong commitment to the team and its leadership can keep people involved even if they occasionally find the process frustrating.

It can help to jump-start the process if leaders can draw on existing networks of colleagues loyal to these individuals with the scientific and social skills to be able to contribute to the success of this particular group (Cummings and Kiesler 2008).

Several aspects contribute to the heterogeneity of ID teams. While team members presumably are comfortable with their own disciplinary epistemology, they may not accept the validity of approaches from other disciplines (Miller et al. 2007; Pennington et al. 2013). Typically, much of the discomfort with a new discipline stems from a lack of familiarity with the norms and languages in that discipline (Brewer 1999; Campbell 2005; Eigenbrode et al. 2007; Lélé and Norgaard 2005; Miller et al. 2007; Morse et al. 2007). Disciplinary scientists are likely to view approaches outside their discipline's cultural norms with discomfort, if not suspicion (Holling 1998; Roy et al. 2013). For instance, research paradigms in different fields often differ with regard to motivations for research, methodology, values, objectivity, and what constitutes sufficient evidence to draw conclusions (Cheruvelil et al. 2014; Golde and Gallagher 1999).

Furthermore, scientists with little experience in a discipline outside their own may think that other disciplines' paradigms and norms are uniform and thus may be uncomfortable when they see a disagreement between members within one discipline (Eigenbrode et al. 2007; Lélé and Norgaard 2005). For example, BP scientists may not realize that while some sociologists are interested in solving environmental problems, others are only interested in gaining a theoretical understanding of why environmental problems occur. ID teams may be hindered by divergent norms in how research teams are formed across the disciplines. For example, in BP and engineering sciences, large scientific teams are common. Social scientists are more likely to work alone or in small groups (Campbell 2005).

Although funding agencies require ID research approaches in many requests for poposals (RFPs), in our experience, the funding announcements generally derive from BP- or engineering science-oriented programs within larger scientific agencies. This situation can lead to a preponderance of ID science proposals led by BP or engineering scientists. If these scientists are unfamiliar with the role that SE scientists can play as disciplinary or integrative researchers, they may be added to teams in the middle or late stages of proposal development when it is too late to fully integrate them or their work. This can result in a power imbalance where SE scientists do not contribute to the development of overarching themes or the selection of other team members (Harrison et al. 1998). Inadequate integration of SE components is then often apparent to savvy reviewers (Campbell 2005).

Principles of successful ID scientific team development

Building on this small group and ID team literature, these key principles emerge:

1. The development and management of a successful ID scientific team is complex and takes time.
2. Investment of time in the development of ID team member and/or leader training in social interaction and task skills is critical.
3. The development of group cohesion and identity takes longer in ID teams than in disciplinary ones but is essential to ID team success.
4. Drawing upon existing relationships to design ID teams helps kick-start cohesion, identity, and commitment that will continue through the challenging process of creating a successful ID team.
5. Smoothly functioning small groups require shared goals, shared norms, and clearly structured member positions. It is therefore particularly important to develop and communicate them with ID groups where individuals may not share common expectations.
6. Integrating a critical mass of both BP and SE scientists into the team immediately and consciously presents their efforts as equally important.

Relevance of sustainability transitions theory to successful ID scientific team development

Sustainability transition management (Loorbach 2007; Markard et al. 2012; Rotmans 2005) is a cyclical process designed to enact sociotechnical change through problem restructuring and goal envisioning, in which there is the formation of a common dialog for all participants. In this phase, the group must exist within a niche or "safe space," in order to voice different perspectives, opinions, and experiences. For newly formed scientific ID teams to successfully work together, participants must also feel that they are "safe" to express their ideas and must be open to learning from other disciplines and members of society. The goal of the first phase in both sustainability transition management and ID team development is to formulate shared goals, norms, and expectations. This is also the stage in which the selection of leaders and participants is crucial—participants must be visionaries and frontrunners and have the ability to look beyond their own disciplines and experiences (Rotmans and Fischer-Kowalski 2009).

In the next phase of sustainability transition management, these niches are used to convey institutional changes (new rules, policies, structures, technologies, and so on) which are created and disseminated (Loorbach and Rotmans 2010; Markard et al. 2012). In the case of ID scientific team development, institutional changes can be thought of as ID or transdisciplinary research questions, methodologies, and partnerships. The transition management cycle then goes on to the experimentation phase, where high-risk experiments with a social learning objective are undertaken and applied to the sustainability goals (Rotmans and Fischer-Kowalski 2009). The final phase involves monitoring and evaluating the entire process, including rate of progress, barriers encountered, involvement of actors and participants, and results from experimentation (Rotmans and Fischer-Kowalski 2009). ID teams also undergo an "experimentation" phase, whereby ideas and methodologies are tested and evaluated. Further, ID teams greatly benefit from continuous self-monitoring and evaluation, throughout the process of team formation, development of shared goals and norms, and during research and reporting.

Our ID team case

We use the example of our IAI project "Interdisciplinary Science Team Skill Building through the Study of Socioecological Impacts of Bioenergy Development across the Americas" to implement and assess the effectiveness of these principles. We begin in this section with a description of the relationship of the IAI project to an umbrella set of projects that focus on bioenergy in the Americas. We assess the development of the parent project with respect to the implementation of the principles. Then, in the following section, we describe the specific IAI ID team skill-building activities and, again, assess these activities against the ID key principles.

The IAI project, which began in February 2014 and will end in early 2016, is part of a larger, 5-year US National Science Foundation Partnerships in International Research and Education (PIRE) project that began in 2012. The PIRE project has about 100 student and scientist members spread across Brazil, Mexico, Canada, Uruguay, Argentina, and USA. The IAI team is a subset of the PIRE project, containing 20 students and scientists, all of whom are involved in the PIRE project and drawn from the same six countries. Both the IAI and PIRE projects focus on understanding the socioecological impacts of forest-related bioenergy across the six countries. The IAI project also contains an explicit focus on enhancing scientific understanding of ID teamwork skill development. The IAI project includes activities focused on training student and scientist members to become effective ID team members, especially student member teamwork skills.

The leaders of the PIRE and IAI projects were sufficiently experienced in ID team development to follow many of the above principles. Following Markard et al. (2012), they understood the need for sociotechnical change through a sustainability intervention. Recognizing the need to evolve over time, they began the proposal development several months before the proposal deadline. The IAI project was specifically designed to enhance leader and team member ID teamwork skills through activities described in the next section. However, it should be noted that the PI had over 10 years of experience leading and participating in ID teams. Beginning work together many months before the RFP deadline provided the team with extensive time to interact and cohere, as did frequent virtual videoconferences. Since the IAI team was a subset of the PIRE team that had been working together for some time, most IAI team members already knew each other well and had met in person although they come from six countries and seven universities.

The team leader asked for the creation of leaders for each country, who took charge of integrating research and writing with other members of that country team. This, in combination with prior experience working together, helped to establish member positions within the team. Shared norms of respect, inclusiveness, and sensitivity to potentially sensitive issues across the involved countries, cultures, languages, and disciplines were encouraged and enforced by multiple levels of leadership. Our IAI team includes 8 SE and 12 BP scientists, providing a close-to-even split between these sets of disciplines. The team leader is an SE scientist, and this also helps to ensure that SE scientists are fully involved and integrated into the team. Along with clearly delineated positions with the team, associated roles and tasks were laid out and reinforced throughout proposal development and into

project implementation. For instance, each country leader is responsible for overseeing their subcontract and coordinating hosting meetings and research activities in their country. Thus, the proposal development process was managed to follow the above principles, and this strategy continues throughout project implementation. Although some team members were experienced in ID teamwork and had worked together prior to proposal development, not all had that experience. The next section describes the student and scientist training activities conducted to further enhance member ID teamwork skills.

ID teamwork skill-building exercises

The IAI project work includes two in-person meetings per year, rotating between participating countries. These four in-person meetings provided niches to use as accelerated transition opportunities to train team members in new institutional practices with regard to ID scientific work (Markard et al. 2012). Team members met in Montevideo, Uruguay in May 2014, in Belem, Brazil in July 2014, in Merida, Mexico in February 2015, and in Houghton, USA in May 2015. Team members work together with the larger PIRE team members to conduct an ID scientific assessment of SE, BP, and engineering scientific aspects of forest-related bioenergy development across the countries. Through the PIRE project, the team members also participate in weekly to monthly video and in-person research meetings. This means that members meet virtually or in person, twice a month throughout the year on average.

As part of our IAI project ID team building efforts, we structured our in-person meetings as opportunities to deepen our understanding of each other's work and to learn how to operate more effectively as a team, using classroom presentations, group exercises, and field excursions. Two graduate students who participated in a semester-long course on ID science at Michigan Technological University (described in detail in Knowlton et al. 2014) helped to facilitate the activities along with the project PI and a Co-PI. We asked participants to engage fully in the group work and share feedback in a respectful manner.

During our first meeting in Montevideo, Uruguay, team members participated in a World Café Model of Dialogue (Brown and Isaacs 2005), a facilitated discussion where the whole group was broken into small groups to discuss thoughtful, pre-written open-ended questions. To enable a rich discussion, provide an understanding of the vision of the different disciplines, and reach a common understanding, the groups had diverse compositions, containing students and researchers of different nationalities and disciplines. We asked participants four guiding questions: (1) What is "good science?"; (2) What is "multidisciplinary" research?; (3) What is "interdisciplinary" research?; and (4) How do we create "good science?" Each group discussed one of the questions for 20 min, and then the group members moved to another table to discuss one of the other questions, with one person staying behind as "threadkeeper" to continue the conversations, taking notes and linking the ideas and discussions between groups. After each group discussed the questions, we facilitated a larger group discussion to harvest the ideas and inspirations of the whole group and how they relate to our international, ID team.

In order to gain the level of comfort to work across national and ID boundaries, we included morning activities where participants got to know one another better. For one such "ice-breaker" activity, participants were paired up with a colleague and interviewed each other, sharing information about where they are from, their educational background, experiences with ID science, and something personal or funny. Since listening is an important part of a group communication, participants were asked to practice active listening and, following the exchange of information between the pairs, they were asked to introduce each other to the rest of the larger group.

Following the ice-breaker activity, we launched another small group exercise to identify areas of commonality and differences between disciplines. Groups were composed of researchers and students from different countries and disciplines, and the groups were asked to define and explain the following terms: system; scale; treatment; and control. Next, the groups were asked to discuss their publishing paradigms and expectations for authorship. All small group discussions were followed by a larger discussion with the entire IAI team. Because our IAI group works together as a virtual team most of the time, we also discussed best practices for sharing and collaborating across countries as well as how to bridge language barriers.

To expand our understanding of and appreciation for each other's methodologies, we spent a total of 1.5 days engaged in field activities to demonstrate SE and BP research techniques. The first day involved visiting two local farms near Montevideo. The SE scientists explained to the natural scientists how to conduct interviews in order to generate meaningful data. Two BP scientists proceeded to interview two local farmers in an effort to understand some of the challenges they face in engaging in agriculture in the twenty-first century. This experience allowed the entire group to witness one approach SE scientists use and the qualitative data generated.

The second day was spent in the field. A BP scientist in the IAI team explained the methods she uses for conducting bird surveys, and the SE members of the group then worked in teams to practice this method of counting the birds they could see or hear. Later in the day, another BP scientist in the IAI team explained the steps involved in studying how the extent of the forest cover affects watershed hydrology. Part of this process involved extracting sample branches from several tree species, counting the number of leaves one each branch, weighing the leaves' mass, and graphing the results. The IAI group worked in small teams to employ these methods to

generate data, and the larger team reconvened to share their results. Through these field exercises, all members of the IAI group were exposed to the methods and disciplinary assumptions employed by both social scientists and natural scientists.

During our second IAI in-person team meeting in Belem, Brazil, we spent 1 day allowing team members from each discipline to give presentations about the research paradigm, questions, key variables, data collection, and analysis of their discipline. Several members also presented on ID integration and communication strategies and how to use models as integrative tools in ID research. Another day was spent giving presentations on ID research design and proposal writing and development, including project management and budgeting.

The capstone experience for the six graduate students participating in the IAI project was the chance to work together to craft an ID grant proposal over the course of 9 months. The students were given a real-world RFP from the IAI that related to socioecological sustainability and were given feedback and critiques using the same criteria used by the IAI. First, the team coached the students on the mechanics of ID science proposal writing and how to identify an area ripe for ID research. The students worked together as one team and were coached to establish their own governing rules, expectations, and roles.

Our IAI team established due dates, and expected milestones gave continuous feedback to the student's developing ideas. The students were always given time to work on the proposal during in-person meetings, and between these meetings the student group worked together virtually to accomplish its tasks. The students first wrote a two-page letter of intent, received feedback, and then completed a second draft. Then the student group submitted an extended proposal (six pages), a draft budget, and their CVs to be reviewed by some of the IAI team members. The students also made an in-person presentation of their proposal at the second meeting and received feedback. After receiving comments from the IAI team members, the students completed a final draft which reviewers and IAI project scientists recommended be submitted to the IAI for potential funding. The students declined the offer because of their other commitments. We consider the students' successful ID science proposal writing as an indicator of the effectiveness of our team's ID training.

Together, these activities helped prepare our group to work together, increasing our efficiency and limiting conflict and misunderstanding. We built a common language and shared expectations that provided tools and opportunities for group members to voice objections and concerns, find areas for collaboration and of common ground, and work together to produce high-quality global change-related ID scientific research.

Assessment of effectiveness

As described earlier, we followed the principles for ID team development derived from the literature and from team member prior experience. We also included extensive and explicit additional ID team training, particularly for member students but also for the participating scientists. Our team has about equal numbers of SE and BP scientists. We started from a core group that knew each well. We established clear roles, norms, and tasks. Finally, we invested the time in developing team members' skills in working across disciplinary boundaries.

Many scientists now recognize the need to expand the measures of success for teams conducting ID research beyond the traditional metrics of number of first author publications and grants (e.g., Goring et al. 2014; Wagner et al. 2011). In this section, we discuss how we assess the success of our ID team, using the metrics recently developed for ID teams by Goring and colleagues (2014). These metrics are as follows: (1) knowledge generation, based on the number of ID team publications (regardless of author order); (2) funding success, based on collaborative team-related grants; (3) policy and management outcomes, based on the number of changes due to the ID team research; (4) data and product creation, based on shared data and new software; (5) team functioning, leadership, and training, based on the number of interactions facilitated across disciplines and with stakeholders; and (6) public outreach, based on broader knowledge dissemination (Goring et al. 2014).

Metrics of success for our ID team:

1. Knowledge generation: To date, our team has one published article, another under review, and has begun a third. We consider this a strong publication record for the first year of a 2-year project.
2. Funding success: Our team's ability to successfully garner competitive, external IAI funding is another measure of our success. We were able to work together over time to develop a proposal that met funder criteria. This was not an easy task given our distribution over space, the extensive paperwork associated with having five subcontracts in addition to the lead university and the need to meet highly specific, challenging funder criteria, including having a team comprising participants from at least four member IAI countries. Another project output is the student proposal following the IAI Seed Grant proposal guidelines. This proposal was reviewed by outside scientists, both of whom were impressed by its quality. Their proposal was strong enough to submit to the IAI for potential funding.
3. Team functioning: We assess our success through the number of ID interactions facilitated and the retention of team members over 2 years since the initial proposal development. At that time, we had 11 participating scientists, all from different disciplines within social, natural,

and engineering sciences (knowing that students would join the project as they started their degrees). Ten of these scientists remain active, fully participating team members. The 11th left the team due to taking a new job that precluded participation and was replaced by a scientist who remains an active participant. We have had 11 students take part in the project. Eight remain active team members. The other three participated minimally and left the project due to a lack of time, poor fit with their graduate school stage, and a lack of comfort with one of the two languages (Spanish and English) in which we work (we follow the IAI rule of allowing participants to speak and present in the language with which they are most comfortable, although participants are expected to have a working knowledge of both languages and the IAI requires proposals to be written in English, as did we). Thus, we retained 18 (81 %) of our participants despite four lengthy international travels and meetings and many virtual meetings. We also measure success based on feedback from our funder. Two staff from the IAI attended our first training sessions in Montevideo. Both were pleased enough with our efforts to ask us to guide groups outside our team through similar processes in IAI workshops.

4. Public outreach: Our team will be offering a free, live, online workshop on transdisciplinary, international scientific teamwork and proposal development on global environmental issues from October to November of 2015. This workshop will be widely advertised and is open to anyone from any country in the Americas. We also have a public webpage linked through the Michigan Technological University website, where we plan to publish the results of our collaborative research.
5. The metrics of success that our team needs to work further on are in the "policy and management outcomes" and "data and product creation" categories. We plan to use our ID team research to assist in policy improvement designed to increase local and national SE benefits, while reducing greenhouse gas emissions, increasing energy independence, enhancing socioecological resilience, and minimizing negative socioecological impacts. We will make all of our results and publications available on our team website.

Discussion

Global change problems are inherently complex, and addressing them often requires ID teams consisting of international members who communicate and work together effectively (Fazey et al. 2013; Roy et al. 2013). The challenges of working in such teams are many, including navigating disparate norms, language, and knowledge bases (e.g., Eigenbrode et al. 2007; Lélé and Norgaard 2005). This paper describes our attempt to use these lessons to successfully build ID teamwork skills and to develop and manage an international ID scientific team. We evaluate our process as successful using a variety of metrics recently developed for ID research. This success supports the findings of prior research into successful ID scientific teamwork (Batie 2008; Batterman et al. 2009; Falkenmark and Rockström 2004; Freeman 2000; Jury and Vaux 2005; Lach et al. 2005; Nowak et al. 2006).

Our team demonstrated a unique approach to facilitating international ID team success through specific leadership techniques, intensive workshops, and group exercises. Our approach was based on key principles of successful sustainability interventions, accelerated transitions, and ID team science development (Markard et al. 2012). We describe strategies used to develop the team and increase its skills grounded in the understanding that ID scientific team is complex, time-consuming, and requiring sociotechnical change that could be facilitated through a sustainability intervention (Markard et al. 2012). Our focus on training members on group dynamics and differences in scientific epistemology increased individual ID teamwork skills, outputs, and self-confidence.

The IAI team invested significant time into the development of team member training in social interaction and task skills to expedite the creation of a "safe space" to aid in the process of "forming, storming, norming, and performing" (Tuckman and Jensen 1977). This training took place in the protected niche of four intensive weeklong in-person workshops distant from most members' home countries (Markard et al. 2012). Further, multiple team members with existing strong and positive relationships were chosen to be part of the IAI team, to help initiate cohesion and shared identity and commitment. The World Café Model of Dialogue (Brown and Isaacs 2005) and the ice-breaker activities were particularly useful exercises for bringing the team through the storming stage, where members challenge each other's beliefs about group goals, tasks, and norms, and into the norming stage, where the group members come to develop shared norms and goals. Taking the time to work through and understand these differences through organized training sessions allowed the IAI team to develop group cohesion and shared identity and structure, facilitating a smooth accelerated transition to ID integration.

Spending time understanding different disciplinary values, norms, and methods helped team members absorb new scientific institutionalized norms for work within the scientific sociotechnical system (Markard et al. 2012). This process of identifying and negotiating differences in disciplinary perspectives is a well-known determinant of ID team success (Morse et al. 2007; Winberg 2008). The experience of teaching and producing an ID science grant proposal provided another highly successful way for IAI team members to negotiate disciplinary differences and pursue ID integration. Crafting a truly ID science research proposal requires

integrating information and perspectives from different disciplines into coherent research products (Bennett and Gadlin 2012; Repko 2012; Knowlton et al. 2014).

We have provided evidence that sustainability intervention and training in the new norms of ID sociotechnical scientific systems facilitated increased interdisciplinarity (Markard et al. 2012). Our IAI team building process offers a compelling example of an accelerated transition toward the development of a successful international ID team, one able to successfully publish together, garner additional competitive funding, and implement complex ID, international scientific research designed to help solve global sustainability problems.

Conclusion

The work described here supports the applicability of the key features of sustainability intervention science (Schensul 2009) to increasing ID scientific capacity. The idea of ID scientific teamwork on environmental research questions is not new. There have been calls for an emphasis on this work for decades, as can be seen in Heberlein's (1988) article. Nonetheless, despite decades of often failed practice in creating and managing these teams, few publications present strategies for success that draw from the peer-reviewed sustainability transition, small group and teamwork literature, as well as real-life cases. This article focuses on discussing those strategies within the context of an arguably successful ID team. We showed how the accelerated transition management literature can be used to inform ID team development.

We found that, using the principles identified in this manuscript, our group scores highly according to most of the metrics of success recently developed for ID teams (Goring et al. 2014; Wagner et al. 2011). Our team has been able to attract substantial national and international funding. Our students have absorbed these principles through our training sessions and were able to develop a strong, international, ID proposal that was positively reviewed by outside reviewers. We believe that, while ID team formation is itself a "wicked problem" (Norris et al. 2015), using the principles described here greatly helped us to solve it. We describe our activities used to train our scientists and students in detail in order to assist others in adapting them to their own classes and teams. Finally, we believe that the principles, processes, and tools we used hold value for other groups beginning to form and manage their own ID teams.

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