Handbook of Environmental Fluid Dynamics
Overview and Fundamentals
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Interdisciplinary Dynamics in EFD Research

Publication details
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Published online on: 12 Dec 2012

Accessed on: 11 Dec 2018
Environmental fluid dynamics (EFD) deals with the study of complex systems that integrate natural, chemical, biological, and physical processes with anthropogenically altered systems. From climate change to wastewater treatment, policy-relevant decisions are often based on EFD research. Hence, EFD is multidisciplinary and its applications and solutions have an inherent human element. This is a sensitive topic in applied scientific research with associated difficult questions, which must be addressed by interdisciplinary teams. Typical questions include: How do we facilitate effective interdisciplinary research (IDR)? How can a team of scientists wrestle with the necessary social and political choices in order to collaboratively produce new scientific knowledge? Who gets credit? How are data and resources shared? What is the appropriate level of trust? How does one negotiate new knowledge and the role it may play in environmental decision making? This chapter provides guidance toward meeting scientific and policy-related goals for researchers interacting in a multidisciplinary framework with an emphasis on communication among researchers of various backgrounds, as well as communication between researchers and policy makers.

In this chapter, we use the definitions proposed by the National Research Council (NRC, 2001) to define multidisciplinary and interdisciplinary. Namely, *multidisciplinary* indicates a “collaborative approach involving many disciplines,” and *interdisciplinary* “implies integration of multidisciplinary knowledge” (NRC, 2001, p. 8).

In order for EFD research to effectively inform current environmental policy decisions, engineers must first be able to communicate with collaborative research partners, spanning multiple disciplines, and second, they must be able to communicate with local policy and decision makers, who have different disciplinary lenses for understanding environmental issues (NAS, 2005). Successful multidisciplinary and IDR begins with clearly defined and functional lines of communication among team members. Likewise, effective communication is necessary to integrate natural and human systems research into environmental policy design and planning efforts. Participants in an interdisciplinary team are bound together in interdependent relationships, and the integrity of their work depends upon developing a shared vision for the project, mutual learning, and satisfying collaboration experience.

*Aims and Goals of Coupled Natural–Human Systems Research Projects*: Biocomplexity in the Environment (BE) was launched in 1999 and was one of NSF’s priority areas. It is no longer run as Biocomplexity; today, related work is typically funded through the Dynamics of Coupled Natural and Human Systems competition. The idea behind the Biocomplexity program was to provide multiyear funding to promote new approaches to investigating the interactivity of biota and the environment. BE was one of the first interdisciplinary funding opportunities that was explicitly designed to foster research and education on the complex interdependencies among the elements of specific environmental systems and interactions of different types of systems. All kinds of organisms and environments, from microbes to humans, fit within the BE framework. Biocomplexity projects were set in diverse environments ranging from frozen polar regions and volcanic vents to temperate forests and agricultural lands as well as the neighborhoods and industries of urban centers. The key connector of BE activities was complexity. Research on the individual components of environmental systems provides limited information about the behavior of the systems themselves, so BE projects were designed to investigate the dynamic interactions of systems, often at multiple scales.
In this chapter, we provide guidance for successful interdisciplinary EFD research projects using as an example a coupled natural–human (CNH) system project that includes various aspects of EFD research situated within a larger ecological, social, and political context. Note that reviews of CNH system research in general can be found in a number of publications including Liu et al. (2007), the special issue on “Biocomplexity in Coupled Human-Natural Systems” published in Geoforum (Walsh and McGinnis, 2008), as well as in Vajjhala et al. (2007). In this chapter, we highlight the role of interdisciplinary collaboration in the context of EFD-focused research. Such collaborations are necessary to investigate the dynamic interrelationships among human and natural systems; however, such collaborations are challenging and require collective communication competence among all of the disciplinary experts on the team (Thompson, 2009).

3.1 Introduction: Interdisciplinary Research

IDR has a long, rich history that disciplinary experts are still struggling to learn from due to the evolving complexity of the issues interdisciplinary teams are asked to tackle. IDR typically targets current and complex issues facing today’s citizens. Historically, IDR was linked with government agencies and industrial advancement. One of the first IDR grants awarded was in 1930 to a team of chemists, engineers, physicists, and meteorologists investigating the dynamics of steam boiler explosions (Wolfe, 1981). Since then, IDR laboratories have launched various thematic research programs across the nation. The National Science Foundation (NSF) was founded in the late 1950s, and federal support for applied multidisciplinary research increased significantly in that decade. Currently, the NSF sponsors several billion dollars in IDR, including a growing program on CNH systems. CNH research projects tend to expand systemic knowledge of complex, interrelated systems beyond the standard research programs in engineering, the sciences, or social sciences (Liu et al., 2007). In addition to CNH, a number of other large-scale programs have focused on multidisciplinary research from NSF including Human and Social Dynamics (HSD), Long-Term Ecological Research (LTER), National Ecological Observation Network (NEON), and Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI) (Vajjhala et al., 2007).

In the past few decades, as external funding has grown and more opportunities for IDR emerged, studies of the interdisciplinary process itself have followed. Beyond discussions of training the next generation of scientific problem solvers, there has been substantial research and theoretical development regarding the functionality of interdisciplinarity and research team dynamics (e.g., Klein, 1990, 1993, 1996, 2003; Nissani, 1995, 1997; Weingart and Stehr, 2000). Some studies have focused on challenges to interdisciplinary teamwork (e.g., Bauer, 1990; Kostoff, 2002; Pellmar and Eisenberg, 2000; Salter and Hearn, 1993; Turner and Carpenter, 1999; Wear, 1999) and opportunities for interdisciplinary success (e.g., Benda et al., 2002; Cassell, 1986; Gillespie and Birnbaum, 1980; Pickett et al., 1999; Turner and Carpenter, 1999). In our experience, understanding common challenges and opportunities for success is necessary to effectively frame IDR research and engage disciplinary partners in complex interdisciplinary collaborations.

3.2 Elements of Successful Interdisciplinary Projects

In 2007, Thompson completed a 4 year ethnographic investigation of a complex IDR team. The team was participating in an NSF-funded CNH project tasked with investigating the dynamics of urban air quality, greenhouse gases, and natural as well as human impacts on climate change that required the expertise of multiple disciplines (Pataki et al., 2009). The interdisciplinary team members designed a research agenda that included measuring the concentrations of emissions and pollutant gases, tracing their origins, and integrating that data into a computer simulation model while hosting a series of public outreach workshops to solicit the input from local stakeholders. Thompson’s responsibility on the team was to assist in developing and facilitating the outreach workshops by translating scientific findings for the team members and stakeholders. Much of her work was focused on taking notes and facilitating team meetings, coordinating scientific poster sessions, and assisting in systems model building activities. However, during the course of this project she realized, along with the team, that there was a larger story to be told about how IDR teams operate.

The Team included 5 principal investigators (PIs), 14 coinvestigators, and 9 graduate research assistants. Participants represented 12 disciplines including biology, chemical engineering, civil engineering, communication, ecology, geography, hydrology, material science engineering, mechanical engineering, meteorology, psychology, and urban planning. The researchers ranged in age, interdisciplinary team experience, and academic seniority. For example, one coinvestigator was a full professor and retired near the beginning of the project, and it was another coinvestigator’s first year at this university and his first experience working on a formal and funded IDR project. The researchers took on the responsibility of addressing a complex ecological issue but also realized that they needed to negotiate knowledge, science, power, and interpersonal relationships in order to make scientific progress.

The lead PI was in the College of Life Sciences, a second PI was in the College of Engineering, a third was in the physical sciences, a fourth in the social sciences, and the fifth was in the College of Humanities. Three of the PIs were senior, tenured faculty members, and two were full-time research scientists. Each PI was in charge of one of the team’s subgroups. These subgroups were organized around specific aspects of the project, including
measuring greenhouse gas emissions (measurements subgroup), modeling the urban ecosystem (modeling subgroup), preparing a series of outreach workshops (outreach subgroup), and devising emissions management policies (emissions management subgroup); and the steering committee subgroup oversaw data integration. In an attempt to protect the identities of the participants in this case study, team members will be referred to by their role or position in the team.

As the project evolved, Thompson, a trained social scientist, took ethnographic field notes focused on the team’s communicative and collaborative interactions (methods detailed in Lindlof and Taylor, 2002). For example, she was asked to coordinate poster sessions for a series of outreach workshops. In coordinating that event, she met with 12 team members and helped to translate their research process and data into public-friendly poster presentations. Through this process, she gained extensive access to many team members. They invited her into their offices and laboratories, and she used that invitation as an opportunity to ask questions about their expertise, research, and experiences working on the project. These informal, ethnographic interviews informed a deeper investigation of the dynamics of this IDR team. Specifically, she set out to understand: how can a set of disciplinary experts truly integrate their research to produce emergent knowledge? The answer is in the relational dynamics of the collaborative process, which begins with spending time together.

1. Spending time together: The first requirement for team building and developing communication competence is to spend time together. Team members who are open and willing to learn from each other also appear willing to spend time together. One’s willingness to spend time is often related to external variables such as the resources available and the amount and types of outside resistance members felt. In many interdisciplinary projects, team members report that they feel they do not have enough time to discuss, connect, and explore ideas with other team members. Even team members who were initially excited about the project and participated regularly in early meetings later disclosed in interviews that they did not have time to commit because of all of their other academic duties.

2. Practicing trust: The team members openly discussed their desires for trust and the consequences of a lack of trust. Such conversations about trust helped to build the team’s collective ability to communicate. Building trust takes a lot of time, but several theorists have suggested (e.g., Meyerson et al., 1996) that swift trust can help move motivated teams through a transition from temporary trust to a more sustainable, lasting trust necessary for sharing data, analysis, and integrated insights. This team, like other research teams, was working with a common task and finite life span. With tight deadlines, there is not much time for relationship building, so members import trust from previous experiences in an effort to be successful in this situation. Likewise, the more a team practices trust, the more they are able to build—thus, practice becomes the norm and relationships build as shared knowledge about the science builds.

3. Discussing language differences: People from different scholarly backgrounds assign qualitatively different meanings to the same or similar terms. Thus, a major obstacle in IDR is that it is difficult to find a common language because of our entrenched disciplinary specializations and corresponding languages. Many scholars have explored the challenges of language differences in collaborative research projects (i.e., Benda et al., 2002; Glantz and Orlovsky, 1986) and conclude that differences in definitions of jargon often lead to miscommunication and misunderstandings. Therefore, discussing such differences openly is necessary for the team to fully engage in collaborative problem solving.

4. A sense of presence: Senge et al. (2005) articulate the idea of presence in a team context, which involves “deep listening [and] being open beyond one’s preconceptions and historical ways of making sense” (p. 13). Presence is one’s ability to engage in collaboration while being open to experiencing a shift in one’s own thinking. This is often manifested in an expressed motivation to learn, listen, and see the world differently. Sometimes the enthusiasm for mutual learning of this magnitude is contagious and can ripple through the team, creating a positive feedback, building enthusiasm and synergy as the team continues to work and learn together.

5. Reflexive communication: Reflectivity and reflexive talk are terms used to describe the idea that humans, as participants in a complex social system, are able to observe, reflect, and ultimately affect change within their system. In an IDR team, this process is magnified when team members collectively realize the impact of mutual learning and awareness of how that learning, in combination with their own behavior, impacts the group dynamics. Reflexive talk is an opportunity for a team to step back and ask the following questions: How are we learning together? What is working? What needs to change? This type of dialogue helps team members to avoid “groupthinking” and identify processes that facilitate collaboration and understanding across disciplinary divides.

6. A sense of humor: Finally, humor allows us to take advantage of the inconsistencies and incongruencies of a human existence. In teams, humor helps to relieve stress, support group ideals, integrate ideas in creative ways, and show support for common values (Bolman and Deal, 1991). Every team can benefit from the power of laughter, when natural and appropriate. Joking in this team helped to build a sense of community and cohesiveness and ease tension.
3.3 Tools for Facilitating Successful Interdisciplinary Projects

The following activities are critical to facilitating interdisciplinary projects but oftentimes are not performed, as they are not part of the typical scientific training process:

1. Build in trust-building time.
2. Host explicit discussions about language differences.
3. Schedule social time.
4. Confront communication challenges early.
5. Allot time to develop a shared conceptual model of the project.

First, interdisciplinary teams should write project proposals and team agendas to include time for building trust and engaging in reflexive talk. Time is one of the most sacred assets for any researcher, and team members may become frustrated if meeting time is not being optimized. However, it is suggested that time be allotted for team members to recognize and discuss the need for trust and barriers to trust within their team. This time should also facilitate reflexive communication about the team’s relational evolution and development of collaborative capacity.

Second, team managers should make an effort to supplement talk about tasks with explicit discussions about language differences. A common challenge in multidisciplinary teams is overcoming jargon and terminology differences; such barriers can be reframed as learning opportunities for the entire team. Managers should be cognizant of concepts and terms that are not accessible to all members of the team and make room during the meeting time to dissect, discuss, and learn from such differences.

Third, teams might also consider scheduling social time for members to build relationships and share laughter. We recommend that large teams set aside time for members to network and mingle among themselves. Researchers may be much more motivated to participate in collaborative work if some type of social benefit accompanies the professional rewards for participating.

Fourth, negative humor, debating expertise, communicating boredom, and power struggles may be an inherent part of interdisciplinary team dynamics; efforts should be made to confront such challenges before nasty habits become group norms. IDR teams could benefit from the use of a professional facilitator. A professional facilitator can help the team to manage negative aspects of group dynamics. Team members may not know how to confront such conflicts or challenges. Instead of avoiding collaborative research because of the possibility of unpleasant experiences, teams should include funding for a facilitator to help the team reflect upon and navigate through such challenges.

Finally, IDR teams need a map. They need to know how their expertise is connected to the research goal, as well as to each other. Taking several hours early in the project to map out the team’s system can save hours of arguing later. When it comes to linking social, ecological, and engineered systems, there is a lot of room for miscommunication and misunderstanding; however, a visual depiction or qualitative systems map of the project can facilitate communication that transcends any one team member’s disciplinary expertise. There are several ways to develop such maps; the only rule is that all team members contribute to the process so that they have a sense of shared ownership of the final model. Once the concepts are mapped out, it is equally helpful to have team members mark or locate themselves on the map. Ultimately, if implemented, these suggestions can help avoid pitfalls that are common to IDR research, potentially lead to more productive research projects, or aid in attaining a more efficient level of communication more rapidly.

References


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