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Water Diplomacy: Perspectives from a Group of Interdisciplinary Graduate Students

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Abstract: Water management challenges are multifaceted, often involving issues of water availability, quality, access and equity. It is increasingly recognized that professionals trained to work in traditional disciplinary roles are ill-equipped to address complex issues such as water that transcend both geographic and disciplinary boundaries. A growing number of interdisciplinary doctoral programs, including the Water Diplomacy Integrative Graduate Education and Research Traineeship (IGERT) at Tufts University, have formed to respond to demand for progress in this area. This paper presents a Water Diplomacy IGERT student perspective on the benefits and challenges of interdisciplinary water education. First, we find that articulating a set of shared principles helps to build a strong research community, which in turn shapes the research approach and perspectives of participating students. Second, we recommend students clearly state uncertainties and assumptions to tackle the challenge of working with multidimensional complex systems. Next, we advise that students collaborate with researchers and partner organizations to gain exposure to different approaches outside of their discipline, and to increase breadth of knowledge while maintaining sufficient depth. Finally, we recommend that students take an active role in program leadership to ensure balance between program and student development. These difficulties are not unique to water education, and therefore we hope this discussion can help inform future interdisciplinary education and research efforts.

Keywords: *interdisciplinary education, water resources, IGERT, student perspective*

In the last decade, water problems have emerged as one of the most significant global concerns for reasons including availability (McDonald et al. 2011, Vörösmarty et al. 2000), quality (Verhoeven et al. 2006), access (Dagdeviren and Robertson 2011), and natural hazards (Douben 2006). Meanwhile, the number of interdisciplinary graduate programs in universities around the U.S. has increased (Association for Integrative Studies 2014) and there is a growing consensus that interdisciplinary approaches are an essential component of the education required to prepare students to solve some of society's biggest problems (Gewin 2014; Derrick et al. 2011).

Several have written on the call for interdisciplinary approaches to specific water-related topics, to name a few: water quality (Haygarth et al. 2005), ecology (Wassen and Grootjans 1996), and public health (Rodriguez-Mozaz and Weinberg 2010). Perhaps as a response, the U.S. has seen an increase of such programs in the field of water, e.g., WaterSENSE at the University of California, Riverside (http://watersense.ucr.edu/), I-WATER at Colorado State University (http://i-water.colostate.edu/), and CCWAS at the University of California, Davis (http://ccwas.ucdavis.edu/). Since 1998 the U.S. National Science Foundation (NSF) has funded Integrative Graduate Education and Research Traineeship (IGERT) programs at universities around the country to provide collaborative interdisciplinary education and research opportunities to more than 4,000 doctoral students around an integrating theme (NSF 2014a).

These training programs, while relatively new, already show signs of success. A study following IGERT students through their studies and post-graduation found several key outcomes of the

NSF-IGERT program: (1) 75% of IGERT students incorporated at least two disciplines into their dissertation compared with 61% from non-IGERT students; (2) IGERT students finish their degrees on average a semester earlier than non-IGERTs, and (3) IGERT students value their training and 94% recommend the program to others with similar career goals (Carney and Neishi 2010). This positive feedback has encouraged more universities to develop formal interdisciplinary programs.

In 2011, Tufts University started an IGERT program on the theme of Water Diplomacy. Water Diplomacy is the theory and practice of implementing adaptive water management for complex water issues, developed by a group of researchers at Tufts, MIT, and Harvard. The Water Diplomacy (WD) approach diagnoses water problems, identifies intervention points, and proposes sustainable solutions that are sensitive to diverse viewpoints and values, ambiguity and uncertainty, as well as competing needs (Islam and Susskind 2012).

The WD IGERT aims to educate the next generation of water professionals as individuals who view water not as a fixed resource, but as a flexible resource that can be sustainably shared. The anticipated outcomes of this program are to create new avenues for resolving water conflicts by educating students to think across boundaries, integrate knowledge and action, and develop non-zero sum solutions. The main goal of this paper is to offer a case study illustrating the benefits and struggles of an interdisciplinary graduate education focused on water resources and solving water issues through synthesis of student perspectives from the WD IGERT program at Tufts.

Core Principles of Water Diplomacy

The identity of the WD program has evolved since its inception in 2011 as student cohorts have joined each year and shaped the student experience and program vision. Students in the WD IGERT come from a range of backgrounds including civil and environmental engineering, law and diplomacy, agriculture science, and biology; some students enter the program after years of professional experience while others enter directly after completing their undergraduate studies. Some, particularly engineering students, have worked on water issues for years while others come from intersecting fields but have not previously studied water issues directly. Given such a broad range of backgrounds, the student experience has varied significantly and as a group we have found that the common thread is not a set of skills, but rather a shared perspective. Through participation in WD courses such as Water Policy and Politics, the formation of research topics, and engagement in projects with peers, WD IGERT has shaped the perspective of participating students. This perspective can be summarized in four core principles that we feel are critical for solving complex water problems:

i. Science and values are both important in addressing water problems.
ii. Effective problem solving requires recognition of the strengths, limitations, and boundaries of disciplinary lenses.
iii. Water systems are complex adaptive systems.
iv. Researchers must strive to produce actionable knowledge despite inherent uncertainties.

These core principles are drawn from both our own research experience and a range of interdisciplinary scholarly articles summarized here. Resolving conflicts between multiple users of a water system requires not only an understanding of the facts but also the values of the stakeholders involved (Islam and Susskind 2012). While not all researchers are directly involved in stakeholder engagement, an understanding of the role of values in shaping feasible solutions enables researchers to appreciate the boundaries of their expertise. Water systems, similar to other complex adaptive systems, are characterized by emergent behavior, unpredictability, boundary-crossing and co-evolution (Islam and Susskind 2012). This complexity generates considerable uncertainties and challenges for researchers and practitioners aiming to produce actionable knowledge. Synthesizing data and knowledge from multiple disciplines can enhance our understanding of such systems (Sivapalan et al. 2011). However, decisions must proceed regardless of the resolution of substantial uncertainties (Lempert 2002). WD IGERT students recognize and clearly present

the uncertainties in their work to contribute to synthesis efforts and inform decision making.

The four core principles of Water Diplomacy are central to both the program and students' academic and personal development as interdisciplinary water professionals. Students in the program attest that the WD perspective has shaped their research questions, the types of collaborations they pursue, and their post-graduation plans. Through discussions and a brief survey, we see evidence of this effect. For example, one student's career goals have shifted from a domestic to an international focus with the aim of working at the intersection of ecological and development issues. Another student explained that while her career goals haven't shifted, the types of collaborations she pursues have expanded beyond engineering to include political science and decision science.

Who are water diplomats?

Interdisciplinary professionals who contribute to the resolution of complex water problems that include: (i) multiple stakeholders with conflicting or divergent interests and (ii) sources of uncertainty in either or both the scientific or sociopolitical domain. Water diplomats facilitate sustainable water solutions by problem-solving with a mutual gains negotiation approach and synthesizing information across disciplinary boundaries and sociopolitical perspectives. Water diplomats are literate in multiple water-related academic and applied fields.

Challenges and Lessons Learned

As students in the WD IGERT program at Tufts, we are scientists conducting experiments for our dissertations while simultaneously the subjects of an experiment ourselves. Amid rapid growth, interdisciplinary doctoral education is a new frontier and each program is discovering new challenges and new solutions along the way (Graybill et al. 2006; Pinter et al. 2013). Many have written on this subject, highlighting the potential benefits of interdisciplinary education in solving cross-discipline problems (Nyquist and Woodford 2000; Derrick et al. 2011) while also acknowledging the difficulties, namely in aligning targeted programs with student learning outcomes (Borrego and Cutler 2010), developing successful departments for interdisciplinary studies and pursuing careers as tenured academics (Gewin 2014). Here we discuss three challenges and offer our lessons learned in tackling them through the WD IGERT program: 1) managing uncertainty while creating actionable knowledge, 2) trading off disciplinary depth with interdisciplinary breadth, and 3) balancing program and student development.

Managing Uncertainty and Creating Actionable Knowledge

The complexity of resolving water issues can be immobilizing when one considers the technical, social, political, and economic implications of a single decision. In addition, each component carries uncertainty in the estimate – whether it is in model error, projections about future climate, or imbedded in complicated politics and behaviors. Accounting for these uncertainties is a daunting challenge. WD IGERT students share a common perspective that we must find ways to recognize and manage uncertainty without being paralyzed by it. New interest in socio-hydrology in water research (Sivapalan et al. 2012) and recent efforts by the National Science Foundation for research on coupled human and natural systems were motivated by the recognition that modeling a system from the technical perspective often does not capture system complexities, and that the scope should be expanded to consider social dynamics (NSF 2014b). Similarly, WD IGERT students share a common view that a technical solution is one element in solving a water issue, but that more often than not it does not serve as a complete solution for all stakeholders. As student researchers we carefully incorporate information we know is uncertain, often qualitative in nature, to better represent the system (or issue) as a whole and arrive at feasible solutions.

One main motivation for acknowledging uncertainties in our work is the desire to create actionable knowledge. Actionable knowledge refers to the knowledge needed to have external validity and relevance to the context of the problem (Argyris 1996). The phrase "actionable knowledge" has been defined in many contexts

specific to climate (Meinke et al. 2006), water (Islam and Susskind 2012), and doctoral research in general (Coghlan 2007). Based on discussion and surveying within the WD IGERT program, students are largely more interested in actionable research, developing feasible methods and solutions that the broader community can use and understand, rather than addressing a narrowly defined disciplinary question through theoretical contributions. This underlying commonality among students in the program has helped foster cross-collaborative research projects such as screening level models, review articles, and the use of Geographic Information Systems to answer questions covering a wide range of water issues. However, one major challenge in creating actionable knowledge when there are many unknowns and uncertainties in the system is the number of assumptions needed in order to construct a reasonable and tractable framework. As a first step towards creating actionable knowledge, WD IGERT students clearly communicate the scope, assumptions, and uncertainties in their individual work. Through collaborations with other researchers and partners (e.g., the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, The Global Environment Facility, etc.), students from IGERT and other interdisciplinary programs can contribute to a synthesis of knowledge for decision making.

Knowledge Tradeoffs: Expanding Depth vs. Breadth

Graduate students are continuously evaluating how to balance their time: whether to broaden their skill sets by spending time learning a new concept or method, enrolling in more classes, or taking an internship, versus keeping a narrower focus by digging deep into their specific discipline and moving on a more direct path toward graduation. The challenge of expanding one's breadth across subjects versus depth in a single focus area is further exacerbated for interdisciplinary students who may value the more "winding" path as a primary part of the experience, and are similarly expected to spend a significant amount of time outside their disciplines. The NSF-IGERT program formalizes this particular tradeoff in a "T-exercise," where students identify their current breadth/depth ratio along with goals to expand and deepen through the program. The concept of a "T-shaped water professional" originated in the 1990's in the management and business literature (Hansen and Von Oetinger 2001). Uhlenbrook and Jong (2012) from UNESCO-IHE and McIntosh and Taylor (2013) adapted the T-exercise to identify the skills and knowledge necessary to create "water professionals of the future," who are innovative in solving water problems and in creating new cross-disciplinary approaches. Others in the literature have developed a similar concept, defining one's "tree" with interdisciplinary branches and a disciplinary trunk (Gewin 2014).

Figure 1 illustrates the T-exercise, where "T" is a metaphor to frame the balance of disciplinary depth and interdisciplinary breadth required to address complex and emerging water problems. The vertical section of the "T" represents disciplinary knowledge (focused and deep) while the horizontal blocks represent knowledge across disciplines (broad and multifaceted). WD IGERT program elements support students in creating an individualized curriculum ("T" depth) that is transferrable across disciplines ("T" width).

One important component of the "T' is the student's previous exposure to either interdisciplinary or disciplinary water knowledge. This can highly impact a student's experience, as those who join with strong prior interdisciplinary experience may not find value in expanding their breadth while those that join without exposure to other disciplines may change the shape of their "T" significantly. The majority of student applicants for the WD IGERT program come from a strong disciplinary foundation and seek to increase the breadth of their water knowledge.

One way to navigate the tradeoff between breadth and depth is to collaborate with faculty and peers in other disciplines. Developing the literacy to engage in primary research papers with peers by applying methods across disciplines is a critical skill for an interdisciplinary professional and is a goal of many WD IGERT students. Several examples of methods applied include system dynamics modeling, multi-objective optimization, game theory and negotiation techniques for water conflicts, and methods for coding interview and qualitative data. One specific example from the WD IGERT is the development of a GIS-based

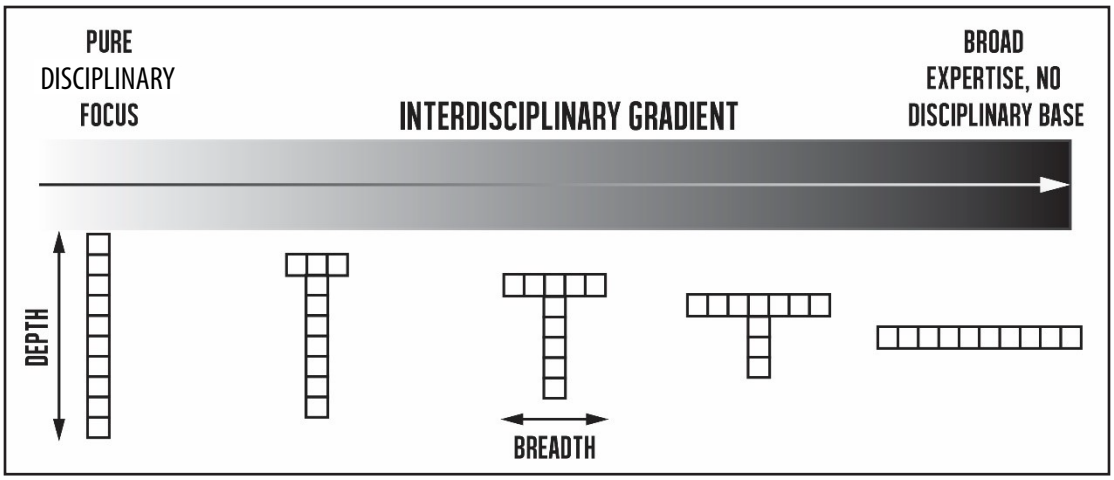


Figure 1. Interdisciplinary gradient and "T" exercise.

tool for indexing wetlands based on hydrology, a combined effort between water resources engineers and a biologist. Taking the time to work on collaborative projects, alongside a dissertation, is a way to broaden the "T" and gain experience in conducting interdisciplinary research. Another approach to broadening the "T" is applying methods from multiple disciplines in individual research. However, this approach takes substantially more time to do well and poses significant challenges for balancing disciplinary requirements with development of interdisciplinary expertise. The WD IGERT program is a platform designed to provide student leadership opportunities, resources for expanding the breadth of knowledge related to water, and work within the academic system to make relevant courses, retreats, and colloquia that support rigorous training.

Funding agencies and researchers have recognized the need for student programs to train participants in effective teamwork skills to address interdisciplinary problems, especially to succeed in receiving funding (Link et al. 2013, NSF 2014a). Specific NSF programs such as Coupled Natural and Human Systems (NSF 2014b), IGERT, and the new NSF Research Traineeship program (NSF 2015) are evidence of the call to expand interdisciplinary graduate education. Increasing efforts like these across the country will only encourage more students to take time and recognize their own "T" aspirations, perhaps an important step in defining personal career and academic goals to achieve with the help of an interdisciplinary program. We recommend that interdisciplinary programs provide the resources to expand the breadth of a student, while supporting the need to balance this with disciplinary knowledge. One way to understand this balance is for students in WD IGERT and similar programs to publically share lessons learned through blogs and academic publications.

Balancing Program and Student Development

The WD IGERT program aims to educate students in Water Diplomacy while simultaneously developing a program identity in this emerging field. The WD IGERT has designed several programmatic elements to stimulate both program and student development including a weekly colloquium and an annual retreat. The Water Diplomacy Colloquium is a weekly meeting of WD IGERT students and faculty that serves as a forum to discuss Water Diplomacy theory and practice and for students to test and present new ideas. Additionally, faculty and students from across Tufts University interested in the week's topics are invited to join the discussion. Together, students and faculty grapple with the definition of Water Diplomacy, explore research methods, and review case studies of water diplomacy concepts in practice. For students, this is both an exciting opportunity to contribute to a new concept and a delicate balance between program and personal development.

Given the time challenges and multiple commitments of IGERT students described

above, it is crucial that time spent in group activities and discussions is useful for student development. Through interviews of students in the program we found that most students agree that certain activities, such as discussions of research methodologies used across fields and establishing a common language for key interdisciplinary topics, are valuable for student development because they provide both the background and the vocabulary to collaborate efficiently across disciplines. In contrast, discussions aiming to advance the theory of water diplomacy were agreed to often be less useful. For example, debates over how to refine the process of applying water diplomacy were hard to connect to student work because few students have the opportunity to directly engage with active negotiations through their research. Additionally, the open ended nature of these discussions makes resolution within the allotted time difficult, cutting into time planned for student presentations and feedback. Advancing the theory and practice of Water Diplomacy is an important aspect of the program, but we have found that these discussions are better suited for a different forum such as the annual retreat held each fall over the course of a weekend. The aim of the retreat is to allow space for deep discussion, set goals for the coming year and foster a sense of community. We have found that away from weekday demands, there is space to fully engage in the subject and to connect the concepts to our individual research programs and plans. Another successful forum to delve into program development is the series of seminars dedicated to a particular aspect of Water Diplomacy. During one semester, two faculty members led a three-part series of talks on community engagement, an aspect of Water Diplomacy in need of further development, and invited students and faculty interested in the topic to attend. Focusing efforts on one aspect of Water Diplomacy and involving researchers from outside the core IGERT group made these events a success.

Since the inception of the WD IGERT program in 2011, our collective understanding of Water Diplomacy as a new field, including the methods used and research questions asked, has evolved. This evolution was shaped by the students and faculty involved who chose to allow the flexibility within the program structure that could facilitate such growth. Some students have used this flexibility to define the program in a way that fits with their research interests and home department requirements. For example, one student from the biology department found that extending water diplomacy concepts of stakeholder consultation and mutual gains to address ecosystem water needs was a novel contribution to the field, and a clear way to connect theoretical research questions with active policy debates. However, the developing nature of the WD field also challenged students to solidify research topics and explain their work to outside groups. For instance, the WD IGERT program requires that students address an interdisciplinary Water Diplomacy research problem in their qualifying exam proposal. Some students found that the evolving nature of the program made the integration of Water Diplomacy concepts into their research proposals more difficult. Clarifying the distinction between student expectations and program goals can ease this obstacle.

Flexibility has been an important strength of the WD IGERT. Student leadership in shaping the program, from setting annual group goals to chairing discussions on program improvement, has been critical to making the best use of this flexibility. Students are the best advocates for their own needs, particularly in newer interdisciplinary programs where advising faculty rarely were educated in similar environments. By taking an active role in program development students can ensure that time and group resources are used in a way that supports their progress. Faculty support for student initiatives and program flexibility facilitate such efforts.

Conclusion

Researchers and funding agencies recognize the need to expand programs that train students in effective teamwork skills for addressing interdisciplinary problems; the recent spike in related programs and calls for proposals is evidence of this recognition. In the field of water resources there is strong interest in interdisciplinary approaches to address global challenges such as water quality management, water for ecosystems, and public health. Universities across the country have developed programs to provide students

with an interdisciplinary education; the Water Diplomacy IGERT at Tufts University is one example of such programs. Despite progress and evidence of initial success, challenges and barriers to successfully implementing this interdisciplinary graduate training remain.

In this paper we offer a students' perspective on how the WD IGERT program has shaped our research, the struggles of interdisciplinary education, and recommendations for building an interdisciplinary graduate research program. In summary, we observe that in building a research community of students from varied backgrounds and departments, a program can benefit greatly from identifying core principles. For WD IGERT, these principles connected students on a level beyond research methods and questions, enhancing a shared vision.

We also offer a perspective on three challenges faced in development of the WD IGERT program. We find that although the complexity of resolving water issues that contain technical, social, political, and economic dimensions can be immobilizing, clearly stating uncertainties and assumptions helps students gain traction in analyzing complex systems. Next, we find that many students in interdisciplinary programs are challenged by the desire to increase the breadth of their knowledge while fulfilling disciplinary requirements. Collaborations within the WD IGERT group and with outside researchers and partner organizations allow students to gain exposure to different approaches while eliminating the need to become an expert in multiple fields. Further, collaborations with implementation focused and community based partners enable actionable science. Finally, the pursuit to strike a reasonable balance between program development and student development may take iteration. By taking an active role in program development students can ensure that the use of time and other resources facilitates their development; program flexibility and faculty support increase the success of student initiatives. The challenges discussed in developing the WD IGERT program are not unique to water, and therefore we intend for this discussion to help inform future interdisciplinary research efforts and provide guidance to students beginning their interdisciplinary educations.

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